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# Dichotomizing Spelling Errors to Examine Language and Executive Function Abilities in Children At Risk of Reading Failure

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# Dichotomizing Spelling Errors to Examine Language and Executive Function Abilities in Children At Risk of Reading Failure

by

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**Dissertation**

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

**Doctor of Philosophy**

**The University of Texas at Austin**

**August 2011**

# Dedication

This dissertation is dedicated to my loving family.

Thank you for your ever-present encouragement and patience throughout this process.

To my beloved husband, for being infinitely supportive.

# Acknowledgements

This work would not have been possible without the support and guidance of my Dissertation Committee members. I wish to thank Cindy Carlson, Tasha Beretvas, and Greg Allen for their helpful suggestions and for sharing their expertise to further enhance my scholarly work. I would also like to thank Lisa Lasater for providing me with the opportunity to gain extensive clinical experience within the school setting, which served as the impetus for this project. Her dedication to helping children and passion for clinical care is inspirational. It was a privilege training and working with her. Nancy Nussbaum, your mentorship has been invaluable to my professional development and future career in the field of Neuropsychology. Your extensive help with conceptualizing this study, facilitating data collection, and editing my document was instrumental in the successful completion of this project. It has truly been an honor to work with you.

I am grateful to all of the Psychology faculty with whom I have had the pleasure of training and working during my graduate studies. It has been an amazing learning experience. Many thanks and much appreciation to Valerie and Summer for helping me collect data and supporting me through this process. Thank you Kristen for your never-ending help, empathy, and understanding, and, most of all, your friendship. I could not have made it through the program without you.

Nobody has been more important to me in the pursuit of this degree than my family. I would like to thank my parents, whose love and guidance are with me in whatever I pursue. They have been my role models for success through hard work and determination, but most importantly, passion. Finally, I wish to thank my loving and supportive husband for finding me and keeping me! Your endless compassion and devotion have been central to my success and happiness.

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Publication No._____________

Kimberly Anne Kayser, Ph.D.
The University of Texas at Austin, 2011

Supervisors: Cindy Carlson and Nancy Nussbaum

Substantial evidence emphasizing the importance of linguistic systems in reading acquisition, as well as emerging literature identifying the contribution of executive function to linguistic-based difficulties, underscores the importance of clarifying the neurocognitive mechanisms affecting reading performance. Research demonstrating the interrelationship between reading and spelling, coupled with neurocognitive theories of spelling, suggests that analysis of children's spelling attempts may capture more subtle differences in their understanding of how to decode text. This study aimed to determine the utility of applying a spelling error analysis system as a method for differentiating between reading difficulties resulting from executive dysfunction or language deficits in a sample of children at risk for reading failure.

The present study examined the relationship between executive function, language, and spelling achievement in a sample of 82 children aged 6-15 years identified as having a reading deficit and/or diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD). Hierarchical regression analyses indicated language-based skills, particularly word reading, and age significantly predicted the phonemic equivalency of misspellings. Tasks of executive functioning were not found to significantly contribute to performance on phonological spelling; however, analysis of group differences suggest that ADHD and Reading Deficit groups demonstrated unique cognitive profiles, including distinct performances on executive functioning tasks. Exploratory analyses also revealed that ADHD and Reading Deficit groups differed significantly in phonological spelling performance.

Results from the current study provide evidence for the presence of two distinct underlying cognitive processes affecting spelling and, in effect, reading. Current findings have implications for the need to further examine characteristic deficits in language and executive functioning affecting children at risk for reading failure. Findings also provide support for the validity of further investigating the potential to infer differential diagnostic categories using a phonological spelling analysis. The use of an analysis of spelling errors as a diagnostic data source holds promise for a better understanding of reading failure and, ultimately, may contribute to more effective intervention practices.

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# Chapter I: Introduction

The ability to read is a fundamental skill necessary to build knowledge and to progress academically. There exists substantial evidence from research on reading and literacy emphasizing the importance of linguistic and phonological awareness instruction within the early academic years (Berninger, Abbott, Vermeulen, et al., 2002; Grossen, 1997; Stanovich, 1986b; Torgesen, 2000). From a young age, children begin to recognize forms and functions of print within their environment (Perfetti, 1985; Treiman & Bourassa, 2000b). This exposure to linguistic systems provides opportunities for children to become increasingly aware of letter names, shapes, and sounds, developing the basic concepts of letter-sound correspondences (Ehri, 1989; Templeton, 1986; Treiman & Bourassa, 2000b). Building on this knowledge, many children are able to learn how to process and manipulate sounds in words during the Kindergarten and 1st grade years. Establishing a connection between the sounds that make up spoken words and the letters that symbolize these sounds, termed the alphabetic principle, is one of the most important precursors to reading acquisition (O'Shaughnessy & Swanson, 2000). Early difficulties with primary phonological skills are therefore a significant indicator of future reading difficulties or deficits (Ehri, 1989; Grossen, 1997).

The implications of early phonological deficits on later academic performance emphasize the need for more accurate systems for classifying Reading Disorders, referred to as Learning Disabilities (LD) within schools, and for more effective intervention for struggling youth. Poor academic performance in the area of reading is quite common among school-age children, making it difficult to distinguish between struggling readers with and without Reading Disorders. Furthermore, Reading Disorder is one of the most prevalent disorders diagnosed in childhood (American Psychiatric Association [APA], 2000). There exists substantial overlap between Reading Disorder and Attention-Deficit/Hyperactivity Disorder (ADHD) diagnoses, with co-occurrence ranging from 15%-50% (Mayes, Calhoun, & Crowell, 2000). Children characterized as displaying symptoms of ADHD demonstrate academic difficulty in language-based subjects similarly to those with Reading Disorder, leading many researchers to question whether they are overlapping disorders (Bental & Tirosh, 2007; Mayes et al., 2000; Rucklidge & Tannock, 2002). Not only are Reading Disorders and ADHD characterized by weaknesses across academic domains, particularly in the area of reading, but they both present Executive Dysfunctions (ED) as well (Bental & Tirosh, 2007; Marzocchi et al., 2008; Rucklidge & Tannock, 2002). While research has delineated various neurocognitive factors related to each Reading Disorders and ADHD, their similar presentation of language-based difficulties generates uncertainty about the specific underlying deficits contributing to general reading delay (Mayes et al., 2000). In effect, questions arise about how to best identify and treat reading difficulties.

Response to Intervention (RTI) is increasingly used as a method for identifying children with Reading Disabilities, measuring academic understanding, as well as evaluating the effectiveness of instructional programs. RTI is designed to provide students at risk of reading failure with early intervention and to align instruction to instructional need (Fuchs & Fuchs, 2006). According to this theoretical orientation, one can assess and identify struggling students who are Reading Disabled or at risk of

Reading Disability on the basis of their response to treatment. Treatment consists of specialized instruction and early intervention methods that match the academic needs of the student. Student progress must be monitored and instructional adaptations must be applied using ongoing, data-driven decision making to assure academic growth. Essentially, individuals identified as Reading Disabled or at risk of Reading Disability would be those who do not respond to treatment (Denton, Fletcher, Anthony, & Francis, 2006; Torgesen, 2000; Vaughn, Linan-Thompson, & Hickman, 2003).

Using instruction as a diagnostic tool provides measurement of individual performance and progress in response to treatment, as well as valuable information concerning the differentiation between students with disabilities, poor readers, and typically functioning peers (Torgesen, 2000; Vaughn et al., 2003). In monitoring reading progress, phonological awareness skills, including deletion, segmenting, and blending, are assessed in conjunction with fluency to determine reading ability and to guide instruction (Bender & Larkin, 2003). However, these assessments cannot determine *why* the mistakes in decoding are being made (i.e. underlying neurocognitive deficits), but only that they occur and are predictive of future reading ability. Although it is known that effective instruction is crucial for at-risk children to overcome difficulties in learning to read, less is known about *why* some at-risk readers respond to early intervention while others respond more slowly or not at all.

A wealth of untapped knowledge exists within a process similar and interrelated to that of reading – spelling (Rapp & Lipka, 2011; Santoro, Coyne, & Simmons, 2006). Both reading and spelling draw on linguistic knowledge including phonological awareness, vocabulary, and orthography (Berninger, Abbott, Abbott, Graham, & Richards, 2002; Bourassa, Beaupre, MacGregor, 2011; Ehri, 1989; Santoro et al., 2006; Treiman & Bourassa; 2000b). However, spelling is a more complex task, combining both encoding and decoding; therefore, it is typically taught after basic reading skills and simultaneously with continued reading instruction (Garcia, Abbott, & Berninger, 2010; Templeton, 1986). Although spelling skills are acquired after reading skills begin to take shape, the fundamental abilities reading and spelling represent are similar and are present prior to receiving any instruction (Ehri, 1989; Treiman & Bourassa, 2000b). Therefore, as children gain knowledge of letter shapes, names, and sounds, their concept of letter-sound correspondences is represented by early word spelling errors.

As children develop, the quality of their misspellings changes dramatically, reflecting their knowledge of the spelling system. For typically functioning children, spelling attempts become increasingly phonetic, providing evidence and implications for the development of phonemic awareness (Treiman & Bourassa, 2000b). Researchers describe this progression of misspellings in four stages – precommunicative, semiphonetic, phonetic, morphemic/transitional – which progress from unintelligible or unrecognizable forms of words to spellings that bear closer resemblance to the words' sounds. These stages occur during the early development of spelling acquisition and typically result in the development of phonetically correct spelling (Bourassa & Treiman, 2001; Cornwall, 1992; Ehri, 1989; Treiman, Cassar, & Zukowski, 1994).

The pattern of spelling errors, phonetic versus dysphonetic, and the skill progression demonstrated by the type of the spelling error are predictive of linguistic knowledge and, hence, later reading achievement (Ehri, 1989; Treiman & Bourassa, 2000b). Therefore, dichotomizing spelling based on the phonetic equivalence of errors children make, rather than on the accuracy or inaccuracy of reading and spelling, may reveal subtle differences in neurocognitive functioning, distinguishing between struggling readers with and without language deficits. Phonemic analysis of spelling errors thus holds promise for better alignment of instructional methods based on the child's need, increasing the likelihood of greater and more effective response to intervention.

The purpose of the present study was to examine the relationship between executive function, language, and spelling achievement in a sample of children at risk for reading failure. This study involved the application of a spelling error system of analysis to determine whether phonetic versus dysphonetic misspellings could be attributed to neurocognitive deficits in language and executive functioning. Furthermore, this study aimed to determine the utility of using spelling as a method for differentiating between reading deficits resulting from executive dysfunction or language-based deficits. Analysis of errors in spelling may potentially contribute to existing neuropsychological profiles of struggling readers and, ultimately, provide insight into the definition and classification of Learning Disabilities. Thus, analysis of spelling errors holds promise for better treatment selection, increasing the likelihood of greater response to intervention. This study sought to determine the extent to which spelling error analysis can aid in the explanation of reading performance.

# Chapter II: Literature Review

The following sections provide a foundation for using spelling as a diagnostic tool to identify areas of deficit related to reading difficulties. This review examines the current literature in the fields of reading and neuropsychology. The initial sections address the history of diagnosing Reading Disorders and issues with current methods for identifying children at risk of Reading Disorder. Following sections provide an illustration of the relationship between reading and spelling, as well as a description of underlying physiological and neuropsychological correlates of reading and spelling, according to neurocognitive perspectives. Building off of this information, the final sections review the developmental stage theory of spelling and suggest ways to improve upon current spelling assessment measures in order to access neuropsychological correlates of reading deficits.

## *Origin and Premise of RTI*

Since its inception, the Education for All Handicapped Children Act, enacted by Congress in 1975, established the provision to support states and localities in protecting the rights of individuals with disabilities within the educational domain (Education for All Handicapped Children's Act of 1975). This law was one of the first major federal programs designed exclusively to aid in the education of individuals with disabilities and aimed toward providing sound methods for identifying and serving individuals with disabilities within the school system. The law, now referred to as the Individuals with Disabilities Education Improvement Act (IDEIA), has been revised many times since its establishment and, as with the reauthorization of any law, incorporates altered and more current interpretations to reflect the advancements made within the field of special education. The most recent amendments were passed by Congress in December 2004, effective July 2005 and published August 2006, and align with the regulatory requirements of the No Child Left Behind Act (Individuals with Disabilities Education Improvement Act [IDEIA], 2004; No Child Left Behind Act [NCLB], 2002). Revisions to this federal register most dramatically impacted the system by which schools identify students with specific learning disabilities. Prior to the 2004 amendments, the ability-achievement discrepancy approach was selected to determine special education eligibility for children with specific learning disabilities, which mandated "the use of a severe discrepancy between intellectual ability and achievement" in one or more areas (Individuals with Disabilities Education Act [IDEA], 1997). The new regulations now require "that the criteria adopted by the State must permit the use of a process based on the child's response to scientific, research-based intervention" (IDEIA, 2004).

While the concept of Response to Intervention (RTI) has been around for decades, first appearing in the literature in the 1960's (Bergan 1977; Deno & Mirkin, 1977; Lindsley, 1972; Lovitt, 1967), it has recently regained increasing recognition as an alternative identification method for Learning Disabilities (LD). With the dramatic rise in the number of students identified as having a specific LD, educators and policymakers alike are becoming increasingly concerned about the expense of special education services (Fresch, 2007; Fuchs, Fuchs, & Compton, 2004; National Association of State Directors of Special Education [NASDSE], 2006). Therefore, accurate determination of eligibility is vital in order to ensure that those in need of special education will be served. The establishment of acceptable criteria has been highly controversial, and, as the revisions in the law would suggest, there has been much debate over the accuracy of the discrepancy model for LD identification (Fletcher & Denton, 2003; Fletcher et al., 1994; Foorman, Francis, Fletcher, & Lynn, 1996; Lyon, 1987; Siegel, 1988; Speece & Case, 2001). Specifically, concerns have been raised regarding the validity of using cut-off scores to identify risk, delay in access to treatment or intervention for students beyond the years in which intervention is most effective, and limited instructional implications from cognitive testing (Case, Speece, & Molloy, 2003; Fuchs et al., 2004; NASDSE, 2006; Vaughn & Fuchs, 2003). Of greatest concern, is timely and early access to intervention services. Children who do not learn to read by the end of first grade are likely to remain poor readers through their school careers, which is why early identification and intervention is crucial (Adams, 1990; Juel, 1988; Pressley, 1998; Stanovich, 1986b). For these reasons, the notion of conceptualizing LD in terms of a failure to respond to treatment, sometimes thought of in terms of treatment validity, has thus reemerged (Fuchs & Fuchs, 1998). In effect, the focus has shifted toward using instructional response as a tool for identifying children in need of more intense and specialized instruction.

The failure to respond to treatment model, or more commonly referred to as Response to Intervention (RTI), identifies students who are performing poorly or who are unresponsive to generally effective instruction, as compared to the performance of their same age peers and normative scores on benchmark assessments (Fuchs & Fuchs, 1998, 2006; Fuchs et al., 2004; Lyon, 1995). RTI incorporates the practice of providing high-quality instruction that matches the student's needs and the use of a multi-tiered model of educational resource delivery. As a result, academic progress of all students is tracked more closely and with greater regularity, and specialized intervention is provided more promptly to those who are unresponsive to instruction or showing risk for failure. While this approach is recognized as ultimately providing a method for identifying specific learning disabilities, its primary purpose is to simultaneously serve as a preventative practice for any child struggling within the general education classroom (Fuchs et al., 2004). Thus, the purpose of RTI is to produce greater outcomes for all children by applying scientifically based methods for instruction and intervention, as well as to provide more valid means for identifying students who demonstrate an unexpected underachievement and need special education services to improve academic performance (Batsche, Kavale, & Kovaleski, 2006; Gersten & Dimino, 2006). The U.S. Department of Education's Office for Special Education Programs (OSEP) recognized the utility of the RTI approach in identifying specific learning disabilities during its 2001 National Summit on Learning Disabilities after concluding that the discrepancy model is atheoretical and had inadequate researched-based support (NASDSE, 2006). Following, Congress authorized the use of RTI in IDEIA 2004.

### *Intervention Defined*

The application of scientifically based literacy instruction is intended to provide high quality instruction to all children, shifting resources toward the delivery and evaluation of effective instructional methods (NCLB, 2002; National Institute of Child Health and Human Development [NICHD], 2000). By doing so, poor instruction is eliminated as a potential variable contributing to, or even causing, a child's inadequate progress. RTI methods can then differentiate those students who, after receiving effective instruction and excluding other causes (i.e. sensory impairments, mental retardation, and emotional disturbance), still show low performance levels and low rates of improvement for the purpose of determining special education eligibility and classification of learning disabilities (Fuchs et al., 2004; IDEIA, 2004; NASDE, 2006; Vaughn & Fuchs, 2003).

IDEIA defined "high quality instruction" according to findings from the National Reading Panel (NRP), which was established in response to Congress' request for the National Institute for Child Health and Human Development (NICHD) to report on the current state of research-based knowledge about reading instruction. The goal of the NRP was to identify the essential components of reading instruction and the most effective approaches to teaching children to read (NICHD, 2000). After reviewing approximately 100,000 published works about reading instruction, the panel narrowed down their search to several hundred studies that met predetermined criteria for scientifically credible research (Ehri, Nunes, Stahl, & Willows, 2001; NICHD, 2000). Using only this evidence-based research, the panel came to a consensus on recommendations for reading instruction and assessment, recognizing five essential components: Phonemic Awareness, Phonics, Reading Fluency, Reading Comprehension, and Vocabulary Development (Lyon & Chhabra, 2004; NICHD, 2000). From this literature, a consistent framework for instructional criteria has been established.

The purpose of reading is to be able to extract meaning from text. The ability to derive meaning from what has been read (i.e. comprehension) is dependent upon fast, accurate, and automatic decoding (i.e. fluency) and word recognition (i.e. vocabulary; Lyon & Chhabra, 2004; Siegel, 1989; Torgesen, 1998). Fluency and comprehension, two of the five essential components, begin with the accurate and immediate reading of words (Lyon & Chhabra, 2004). Therefore, of great importance in the topic of reading acquisition and assessment are the factors that inhibit the development of basic reading skills, specifically decoding of individual words and vocabulary exposure. For this reason, topics related to the most fundamental of the five essential components of reading, Phonemic Awareness (PA), Phonics, and Vocabulary are of concern. The response to intervention paradigm is predicated upon effective ways of measuring progress and assessment of the major skills thought to be most predictive of basic reading achievement, with specific concern for reading decoding because of its strong link to later reading achievement.

### *The "R" in RTI*

RTI is both diagnostic and prescriptive in that it uses the learning system to determine how a child is performing relative to his/her peers and informs decisions made about a child's future instructional needs. Critical to the success of RTI is the careful screening and analysis of performance data for all students. RTI requires using three types of assessments including 1) universal screenings to determine those demonstrating academic difficulty and need additional instruction and/or further monitoring, 2) diagnostics to determine strengths and weaknesses within various academic and behavioral domains, and 3) instruction (i.e. curriculum based measures) as a diagnostic tool to monitor student progress (Fuchs & Fuchs, 2005; IDEIA, 2004; NASDSE, 2006). The use of adequate initial screeners to assess reading achievement is an important first step in identifying students who are at risk for reading failure. There is general agreement among researchers about the relevant set of literacy-related abilities affecting reading achievement, with specific recognition of the significance of phonemic awareness to early reading decoding (Neuman & Dickinson, 2001; Stanovich, 1986b; Torgesen, Wagner, & Rashotte, 1994, 1997; Wagner, Torgesen, & Rashotte, 1994; Whitehurst & Lonigan, 1998). Reading achievement measures typically measure the five reading components, including phonemic awareness, by such reading tasks as letter-naming ability, word recognition, pseudo-word decoding, oral reading fluency, and comprehension of text (Wagner, Torgesen, & Rashotte, 1999; Wilkinson, 1993; Wilson & Felton, 2004; Woodcock, 1997; Woodcock, McGrew, & Mather, 2001). These scales are used in determining both placement and effectiveness of reading intervention programs.

There has been extensive research examining the integrity of RTI and the degree to which at-risk children respond to increasing levels of intervention (O'Connor, 2000; Speece, Case, & Molloy, 2003; Vaughn et al., 2003). While different approaches were used in defining non-responsiveness, such as post-treatment status using standardized assessment tools versus progress monitoring data using curriculum-based measurement, studies indicate that the students' overall performance on reading assessment measures showed only modest improvements for more than half of the participants at the end of the intervention period (Denton et al., 2006; Mathes et al., 2005; Torgesen et al., 2001). While the proportion of students qualifying as non-responders decreased over both time and intervention level, individual responses to intervention were variable (Batsche et al., 2006; Denton et al., 2006; Fuchs et al., 2004; Fuchs, Mock, Morgan, & Young, 2003).

It is disconcerting to consider that these results are from research-based interventions that use highly trained research personnel who are provided with guidance throughout the intervention process (Speece et al., 2003; Vaughn et al., 2003). Some interventions do show positive results, but others fall short. Results seem to remain quite variable despite the quality of research-based interventions. Realistically, teachers vary in their interest and ability to deliver high quality instruction and to adapt instruction to performance data (Gersten, Baker, Haager, & Graves, 2005; Gersten & Dimino, 2006). Consequently, intervention effectiveness will be even less reliable in practice. Therefore, it is important to focus on to whom we are providing intervention and how the direction of the intervention is decided. If assessments are to be used to place students in intervention and to inform instruction, current reading assessments may not be sufficient in identifying students and informing intervention well enough to provide learners what they need.

Providing intervention to children who do not need it is problematic and especially difficult for schools given their limited resources. The ability to accurately predict which children will struggle with serious reading difficulties is still imperfect. Scarborough (1998) conducted a comprehensive review of early identification research.

Results indicated that all studies continue to report substantial levels of false positives and false negatives (Scarborough, 1998; Torgesen, 1998). In fact, false positive rates from early screening may be as high as 50 percent, meaning that half of the children identified as at risk by early screening may in fact not be at risk (Dickman, 2006). In another review of beginning reading intervention research, over prediction and identification of children at risk for becoming Reading Disabled ranged from approximately 42-69 percent (Jenkins & O'Connor, 2002). One of the major difficulties in measuring for early identification is that the earlier a student takes the assessments, the less precise and valid the measure is in predicting potential Reading Disabilities (Gersten & Dimino, 2006; Torgesen, Wagner, Rashotte, Alexander, & Conway, 1997; Vaughn & Fuchs, 2003). Measurement procedures are not ideal, resulting in missed cases and over-identification (Case et al., 2003; Jenkins & O'Connor, 2002; Scarborough, 1998; Torgesen & Burgess, 1998).

Interventions base their selection of students, measurement of progress, and instructional content off of these reading measures (Denton et al., 2006; IDEIA, 2004; Mathes et al., 2005; NASDE, 2006; O'Connor, 2000; Speece et al., 2003; Torgesen et al., 2001; Torgesen, Wagner, Rashotte, Alexander, et al., 1997; Vaughn et al., 2003). While no measure or battery of measures will ever provide perfect prediction, both the false negatives and positives resulting from current, highly reliable measures, and the variable results from intervention studies, suggest that an important diagnostic component is missing in these assessments (Masterson & Apel, 2000; Scarborough, 2005). Furthermore, these assessments are not providing enough information concerning the needs of at-risk children, resulting in inconsistent responses to interventions. Most interventions focus on phonological awareness tasks because of the vast number of research studies linking reading achievement with phonological assessments (Berninger et al., 2006; Blachman, 1994; Gersten & Dimino, 2006; Whitehurst & Lonigan, 1998). The ability to manipulate sounds, which affects understanding of sound-symbol correspondences, has been established as a major predictor of reading, greatly impacting accurate and efficient word decoding (Hatcher, Hulme, & Ellis, 1994). While this focus on phonological skills is most likely accurate, it may be incomplete. Perhaps the variability in children's response to instruction is a result of such diagnostic limitations. Evidence suggests that the developmental process of spelling captures the nuances of printed English that may be overlooked by these more traditional reading tasks (Masterson & Apel, 2000; Moats, 1995; Read, 1975; Scarborough, 2005; Templeton, 1986; Treiman & Bourassa, 2000b).

### *Link Between Spelling and Reading*

Research shows that spelling and reading are interrelated (Ehri, 1997, 2000; Garcia et al., 2010; Moats, 2005; Santoro et al., 2006). If their cognitive components substantially overlap, using spelling, which requires children to construct their understanding of language without textual cues, may offer more precise information regarding how children process linguistic information. Chomsky (1965) suggested such a concept by theorizing that encoding of speech (i.e. spelling) captures a precise level of linguistic knowledge and results in a fully formed concept represented by the child's spelling creation. Decoding (i.e. reading), on the other hand, approximates the message delivered through text, resulting in coding of signals that is produced as a by-product (Chomsky, 1965, cited in Goodman, 1967).

Generally, much of the literature on reading interventions for children at risk of reading disabilities has focused on instructional methods emphasizing the five components of reading: phonemic awareness, phonics, reading comprehension, vocabulary, and reading fluency. Recent research has directed attention towards evaluating the connection between spelling and reading decoding, attempting to highlight the interrelated skills involved in these processes (Berninger, Abbott, Abbott, et al., 2002; Ehri, 2000; Garcia et al., 2010; Santoro et al., 2006; Wanzek et al., 2006). In order to do so, most studies took the approach of investigating the effect of spelling instruction on outcome measures as evidence for the reading and spelling relationship. Specifically, research has focused on the development and evaluation of interventions that incorporate spelling components in an effort to demonstrate the impact spelling instruction has on reading and spelling outcomes. While the ability to read words correctly may facilitate the ability to spell them correctly, research has shown a bidirectional or reciprocal relationship, indicating that teaching spelling techniques influences word recognition and reading (Berninger, Abbott, Abbott, et al., 2002; Ehri, 2000). Results from reading and spelling intervention studies have provided further evidence to support this claim. Spelling intervention groups appear to outperform comparison groups on reading measures (e.g., word reading and fluency) and measures of spelling administered following treatment across several grade levels (Santoro et al., 2006; Wanzek et al., 2006). By recognizing the contribution spelling has on linguistic knowledge, spelling interventions have been acknowledged as effective methods of early intervention for children at risk for reading disabilities.

Other studies provide further evidence for the similarities between reading and spelling by comparing word-reading and word-spelling performances on reading and spelling measures across various developmental stages (Ehri & Wilce, 1982; Griffith, 1991; Jorm, 1981; Juel, Griffith, & Gough, 1986). In such studies, students were required to read words in isolation, spell words dictated from a list, and distinguish between correct and incorrect spellings of words. Findings indicate that reading and spelling performances are highly correlated across age groups, suggesting that these tasks are measuring similar processes (Ehri & Wilce, 1982; Griffith, 1991; Jorm, 1981; Juel et al., 1986). Interestingly, some studies even suggest that the phonological strategies found to be present in both reading and spelling may actually emerge in spelling earlier than in reading, a concept that may provide further evidence for the utility of early spelling assessment (Frith, 1985; Huxford, 1993; Lindamood, 1994; Passenger, Stuart, & Terrell, 2000).

While these studies provide evidence for the interrelationship of reading and spelling by showing either the effect spelling instruction has on reading outcomes or by demonstrating correlations between reading and spelling measures, they do not clarify the inherent link between these two processes or how this information from spelling enhances our understanding of reading proficiency. Prior to these most recent studies on the reading-spelling link, results from the National Reading Panel's extensive review of the literature on literacy did in fact omit spelling as an essential component of reading instruction (Moats, 2005; NICHD, 2000). Rather, they concluded at the time that spelling would develop as a result of strong reading instruction in phonological awareness, not recognizing the impact spelling may have on reading (Moats, 2005; NICHD, 2000). Theoretically, spelling is a more complex task, combining both encoding and decoding, and requiring individuals to produce a representation of their knowledge without relying on any recognition or cues from print (Garcia et al., 2010; Perfetti, 1997). For this reason, spelling is taught after basic reading skills and, thus, not thought to be as critical of a component (Templeton, 1986). However, as discussed previously, research on spelling interventions now indicate that teaching aspects of spelling in conjunction with reading has been shown to produce increased results in reading and spelling outcomes (Berninger, Abbott, Abbott, et al., 2002; Santoro et al., 2006; Wanzek et al., 2006).

By the nature of its ambiguity, spelling cannot be taught as early on as reading; rather it must be delayed until children have at least some basic reading skills (Perfetti, 1997; Templeton, 1986; Treiman & Cassar; 1997). Wanzek et al. (2006) conducted a comprehensive review of literature between 1995 and 2003 that investigated spelling and reading interventions for students with learning disabilities. Out of the 19 intervention studies examined, 16 began after participants' 2$^{nd}$ grade year (Darch, Kim, & Johnson, 2000; MacArthur, 1998, 1999; Torgesen et al., 2001; Wanzek et al., 2006). That is, only three studies provided some element of spelling instructions prior to third grade. Rather than waiting to incorporate spelling instruction into reading intervention programs in grade 3 or later, perhaps early experimentation with spelling (i.e. inventive spelling) can contribute to the understanding of children's linguistic knowledge (Bear & Templeton, 1998; Ehri, 1989; Gentry, 1982; Perfetti, 1997; Read, 1975; Richgels, 2001; Treiman & Bourassa, 2000b). Specifically, because reading instruction begins so early in schooling and precedes spelling instruction, an analysis of early spelling patterns may be equally valuable as an assessment to inform early, more immediate reading intervention (Foorman & Petscher, 2010; Hauerwas & Walker, 2004; Kessler & Treiman, 2003). Despite the recent recognition of the potential impact spelling has on reading, its diagnostic utility and implications for instruction are still somewhat overlooked (Invernizzi & Hayes, 2004; Templeton, 2003). Therefore, while spelling may not be considered a critical instructional component, its established linguistic link with reading may prove it to be a valuable diagnostic tool and deserving of more in depth research (Caravolas, 2004; Masterson & Apel, 2000; Masterson & Crede, 1999; Templeton & Bear, 1992; Treiman & Bourassa, 2000b).

### *Neuropsychological Correlates*

The high incidence of students who present with reading delays, as well as the heterogeneity of their cognitive profiles, complicates the study and treatment of reading deficits (APA, 2000; Hooper, Wakely, de Kruif, & Swartz, 2006). In order to address the frequency of reading difficulties among school-age children and to capture the nature of various neurocognitive factors contributing to these difficulties, many studies investigate samples of children diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD) and Reading Disorder (Bental & Tirosh, 2007; Mayes et al., 2000; Rucklidge & Tannock, 2002). Reading Disorder and ADHD populations account for a substantial number of students demonstrating poor academic performance in reading domain abilities (Marzocchi et al., 2008; Re, Pedron, & Cornoldi, 2007; Rucklidge & Tannock, 2002). Furthermore, Reading Disorder and ADHD are the most prevalent disorders diagnosed in children and, thus, among school-age populations (APA, 2000). Their prevalence, coupled with their high comorbidity rate and similar presentation within the academic domain, not only generates uncertainty about the specific underlying deficits contributing to general reading delay, but also provides access to a broad range of individuals from which hypotheses can be generalized (Mayes et al., 2000).

*Phonological Processing Systems*

Considerable evidence exists documenting the underlying variables associated with reading (Bradley & Bryant, 1983, 1985; Bryant, MacLean, Bradley, & Crossland, 1990; Snowling, 1995; Stanovich, 1986a). Most notably, research indicates that reading problems derive from phonological aspects of language (Savage & Frederickson, 2006; Strattman & Hodson, 2005). Sometimes referred to as the "phonological core deficit," this view purports that children at risk of reading failure demonstrate below average reading ability due to a lack of awareness and access to the phonology of language and, consequently, experience problems with sound-symbol correspondences (Ouellette & Senechal, 2008; Savage & Frederickson, 2006; Wagner & Torgesen, 1987). According to this model, phonology is critical for phonemic analysis and the ability to discriminate sounds in order to read and spell words (Garcia et al., 2010; Ouellette & Senechal, 2008).

The importance of phonology has been examined in numerous theoretical and clinical studies, with the overwhelming majority concluding that phonological tasks on cognitive measures (e.g. segmenting, blending, and deleting letter sounds) are causally related to word identification skills and reading achievement (Ehri, 1989; Kroese, Hynd, Knight, Hiemenz, & Hall, 2000; Lonigan, Burgess, Anthony, & Baker, 1998; MacDonald & Cornwall, 1995). In a series of meta-analyses conducted by the NRP, systematic instruction in phonics and phonemic awareness consistently resulted in significant effects on reading and spelling outcomes (Ehri et al., 2001). However, examination of longitudinal experimental studies using treatment-control comparisons demonstrated variable effect sizes and diminished treatment effects at follow-up (Ehri et al., 2001; Wagner & Torgesen, 1987). While these findings support the proposed relationship between phonological processing and reading performance, they also reveal minimal improvement in reading ability when compared to typical readers (Denton et al., 2006; Mathes et al., 2005; Torgesen et al., 2001). Thus, the prevailing interventions seem to stabilize reading performance and minimize further delay, but are unable to remediate reading deficits (Batsche et al., 2006; Fuchs et al., 2004; Torgesen, 2006).

Cognitive neuropsychological studies have attempted to answer questions concerning the biological bases of reading performance, as well as provide explanations for mixed results of training studies. As early as the late nineteenth century, Dejerine (1891) described a patient who acquired reading-based impairments secondary to infarction in the left parietal lobe, providing foundational evidence for the link between reading deficit and localized neurological impairment (Dejerine, 1891, cited in Coslett, 2003). Consistent with this early observation and theories presented in reading research, current functional neuroimaging studies illustrate activation of the left temporo-parietal cortex during reading and language tasks, and atypical brain activation in this region in children at risk of reading failure (Gabrieli, 2009; Rapp & Lipka, 2011; Reiter, Tucha, & Lange, 2005). Such results provide strong evidence confirming the etiology of reading deficits to be related to a developmental anomaly in the left temporo-parietal region, which manifests as a psychological deficit in phonological processing (Bradley & Brant, 1978; Gabrieli, 2009; Nadeau, 2003; Pennington, 1991; Purcell, Napoliello, & Eden, 2010; Savage & Frederickson, 2006).

*Executive Function*

While there exists robust findings connecting reading difficulties with brain structures localized in the left posterior (i.e. perisylvian) region of the brain, which is highly involved in processing language functioning (i.e. phonological processing), there is a growing body of research demonstrating additional anomalies in psychological and physiological functioning (Bell, McCallum, & Cox, 2003; McCallum et al., 2006; Morris et al., 1998; Pennington, 1991; Roeltgen, 2003; Snowling, 1995; Stanovich & Seigel, 1994). Several studies have shown that neurocognitive factors associated with executive function contribute to linguistic-based difficulties in struggling readers (Frazier, Demaree, & Youngstrom, 2004). The term executive function itself, let alone its contribution to reading disorders, has been highly debated. Lezak (2004) and Stuss and Alexander (2000) used the construct of executive function to refer to distinct processes related to the frontal lobe that converge conceptually on their general purpose to provide conscious control of thought, emotion, and behavior. Distinctions between aspects and corresponding subregions of executive function have been made, further dividing executive function into two major constructs, hot and cold (Zelazo & Muller, 2005). Hot executive function involves the regulation of affect and motivation, which is associated with limbic system functions and the orbitofrontal or mesial frontal regions (Zelazo & Muller, 2005). Cold executive function includes a range of skills including metacognitive abilities (e.g. planning, problem solving, shifting, organization, flexibility etc.), working memory, and speed of processing, which are typically associated with the dorsolateral prefrontal cortex (Anderson, 1998; Anderson, Jacobs, & Anderson, 2008; Lezak, 2004; Powell & Voeller, 2004; Stuss & Alexander, 2000; Zelazo & Muller, 2005). Of particular interest, for the purpose of this study, are the neural structures and functional implications of cold executive function mechanisms.

Reiter, Tucha, & Lange (2005) presented evidence confirming the presence of marked deficit in multiple aspects of executive function, particularly in the area of working memory, among children with reading deficits when compared to a control group. Additional studies have measured separate, unitary aspects of executive function and indicate that in comparison to typical readers, children with reading deficits display impairments in metacognitive skills (Hooper et al., 2006; Levin, 1990; Marzocchi et al., 2008; McLeskey, 1980; Narhi, Rasanen, Metsapelto, & Ahonen, 1997), working memory (Bell et al., 2003; Mattingly, 1991; Ouellette & Senechal, 2008; Rucklidge & Tannock, 2002; Savage & Frederickson, 2006; Strattman & Hodson, 2005; Wagner & Torgesen, 1987), as well as speed of processing (McCallum et al., 2006; Reiter et al., 2005;

Rucklidge & Tannock, 2002). ADHD, more consistently than Reading Disorder, is commonly associated with deficits in prefrontal executive function and general cognitive control (Alderson, Rapport, & Kofler, 2007). Although few studies have focused on the assessment of executive function in children specifically with Reading Disorder, when assessed neuropsychologically, Reading Disorder groups also exhibit disturbance in executive function, as noted above (Marzocchi et al., 2008; Reiter et al., 2005). While a number of studies were able to discriminate between ADHD and Reading Disorder according to executive function profiles, evidence for overlapping and interrelated deficit areas remains (Bental & Tirosh, 2007; Marzocchi et al., 2008; Mayes et al., 2000; Pennington, Groisser, & Welsh, 1993; Rucklidge & Tannock, 2002). Thus, studies addressing neurocognitive profiles have been unable to reliably determine whether there are similar or unique domains of cognitive functioning disrupting reading acquisition among varying at-risk populations.

Until recently, physiological studies, like neuropsychological assessment, have focused primarily on examining the role of language mechanisms in children with impaired reading. To date, additional neuroanatomical abnormalities have been revealed, exposing greater complexity in the pathophysiology of reading. A variety of experimental techniques, including positron emission tomography (PET) imaging, magnetic resonance imaging (MRI), functional MRI (fMRI), and electroencephalography (EEG), have been used to investigate additional anatomic explanations for reading failure, beyond the characteristic left hemisphere language regions (Coslett, 2003; Reiter et al., 2005). Duffy, Denckla, Bartels, & Sandini (1980) conducted one of the first studies to note atypical activation in the medial frontal lobe and left lateral frontal lobe of children with reading deficits versus without when measuring event-related potentials (ERPs) from EEG recordings. Later studies also found atypical activation in left prefrontal regions, associated with working memory (Gabrieli, 2009; Shaywitz et al., 1998), the middle frontal gyrus, which roughly corresponds to the dorsolateral prefrontal cortex and is thought to play a role in attention and memory (Breteler, Arns, Peters, Giepmans, & Verhoeven, 2010; Hoeft et al., 2007), and bilateral frontal cortices (Hoeft et al., 2006). Consistent with these findings, Turkeltaub, Gareau, Flowers, Zeffiro, and Eden (2003) found that readers typically engaged the left posterior superior temporal cortex, as well as demonstrated engagement of the left inferior frontal cortex. Additionally, they noted the importance of working memory in the acquisition of reading skills as well as provided evidence for its correlation with left and right middle frontal gyri (Turkeltaub et al., 2003). Furthermore, increased activation in the right and left frontal regions has been reported following behavioral intervention programs, indicating compensatory frontal brain activation secondary to remediation (Temple et al., 2003). Although studies have shown neurocognitive and neuroanatomical pathology of the left temporo-parietal and frontal cortical regions of the brain in children with reading difficulties, questions remain as to the nature of the association between executive dysfunction and linguistic-based difficulties.

### *Neuropsychological Mechanisms Involved in Spelling*

Several neuropsychological mechanisms are required for the ability to write. Two general categories exist, linguistic components and motor components, which have proven to continually provide compelling evidence throughout advances in neuropsychological research (Roeltgen, 2003). The motor component refers to handwriting and the physical task of motor output, which is beyond the scope of this review. The linguistic component comprises of two systems, sometimes referred to as the dual-route model of spelling, whereby spelling of words can be produced: lexical and phonological (Norton, Kovelman, & Petitto, 2007; Roeltgen, 2003). The process by which a child accesses word spelling provides insight into the cognitive mechanisms and neural correlates underlying language processes, specifically when deficits exist in one route or the other (Invernizzi & Hayes, 2004; Pollo, Treiman, & Kessler, 2007; Roeltgen, 2003).

The dual-route model postulates that word retrieval involves the use of visual word images, word analogies, and mnemonic rules (Roeltgen, 2003). This whole-word retrieval process is typically used for irregular words that do not follow grapheme-to-phoneme, letter-sound correspondence rules and thus require retrieval from lexical memory, problem solving skills, or additional metacognitive skills characterized as executive functions to translate language to print (Norton et al., 2007; Ouellette & Senechal, 2008). Dysfunction in this area, called lexical agraphia, results in the production of phonologically correct spellings, but impaired ability to spell phonetically irregular words (e.g., words without direct letter-sound correspondence) or words with sounds that may be represented by multiple letters (i.e., ambiguous words; "ph" for /f/; Roeltgen, 2003; Pollo et al., 2007). Typically, children with impaired lexical pathways demonstrate phonetically accurate misspellings (e.g. "fown" for "phone") and maintain preserved non-word spelling, which relies on phonological and language-based skills, such as grapheme-to-phoneme rules (Invernizzi & Hayes, 2004; Norton et al., 2007; Pollo et al, 2007). Executive dysfunction thus contributes to impairment of lexical pathways, lexical agraphia, and results in phonetically accurate misspellings due to an over-reliance on phonetic skills as a way to accommodate for poor memory and metacognitive skills typically relied on for retrieval of accurate word spelling using whole-word processes (Ouellette & Senechal, 2008; Roeltgen, 2003). Neuroimaging studies investigating lexical agraphia show underlying anatomical abnormalities in the posterior angular gyrus, parieto-occipital lobe, left posterior temporal region, and frontal region of the brain, which is consistent with evidence of the role of the frontal region of the brain in studies of some children with reading deficits (Roeltgen, 2003).

The alternative system for accessing word spelling, according to the dual-route model, is the phonological system. Grapheme-phoneme conversions allow for speech sounds to be translated, or phonologically decoded, into letters (Bruck & Treiman, 1990; Treiman & Bourassa, 2000). Using this phonological system, words are segmented into separate sound parts and then sounded out to spell orthographically regular words. Dysfunction in this area, called phonological agraphia, results in phonologically incorrect spellings, or dysphonetic spellings (Roeltgen, 2003). As a result, misspellings are usually not phonetically correct, although frequently they visually resemble the spelling word

(Treiman & Bourassa, 2000a). Children with impaired phonological pathways are typically able to spell irregular words, sight words, and high frequency words accurately, which relies on visual word images and lexical memory thought to be related to executive function skills, rather than phoneme-grapheme conversion (Bourassa & Treiman, 2001; Norton et al., 2007; Roeltgen, 2003). Neuroimaging studies investigating phonological agraphia show underlying anatomical abnormalities or lesions of the posterior perisylvian region and supramarginal gyrus, which is consistent with evidence of the role of the left temporo-parietal region in studies of some children with reading deficits and the localization of the phonological aspects of language (Roeltgen, 2003).

The dual-route model presents neurophysiological evidence of brain function related to lexical and phonological spelling impairment that is consistent with anatomical findings associated with executive dysfunction and phonological processing deficits, respectively. The congruence between these two related, yet separate, theoretical models suggests the possibility of using spelling mechanisms as a way to identify neuropsychological impairment. Predictions regarding neurocognitive functioning and dysfunction can be made based on a child's pattern of spelling errors (i.e., phonetic vs. dysphonetic). Specifically, it would be expected that children with frontal lobe dysfunction would demonstrate impaired executive function and dysfunction of the lexical system, resulting in phonetically correct misspellings. Children with more linguistic-based deficits stemming from the left-perisylvian region would demonstrate dysfunction of the phonological system, resulting in phonetically incorrect, or dysphonetic, misspellings. Since spelling and reading are closely interrelated, investigating spelling error patterns and linking them with underlying neurocognitive dysfunction would provide insight into the cause, identification, and treatment of reading delay. This would be especially helpful considering the similar presentation of various deficits on language-based tasks and the high frequency of children at risk of reading failure within the schools.

## *Developmental Stages of Spelling*

Significant advances in our understanding of the children's spelling processes evolved out of studies examining children's early spelling creations and changes in spelling throughout their development (Berninger, Abbott, & Shurtleff, 1990; Willows & Scott, 1994). Read (1975) concluded that learning to spell is a developmental process, acquired systematically over time with the aid of appropriate instruction geared toward a child's developmental ability level, resulting in increased understanding of the language system (Ganske, 1999; Lutz, 1986; Read, 1975; Shen & Bear, 2000). Many other examinations of children's spellings have provided support for the developmental stages of spelling and its relatedness to reading (Bissex, 1980; Chomsky, 1979; Gentry, 1978; Henderson & Beers, 1980; Read, 1986). Specifically, spelling seems to develop as children gain more abstract levels of word structures and linguistic knowledge (Beers, 1980; Berninger, Abbott, & Shurtleff, 1990; Chomsky, 1979; Gentry, 1978; Templeton, 1986).

The literature presents several theories outlining the developmental stages of English linguistic understanding as manifested through spelling production (Pollo et al., 2007). While there lacks a consensus as to the number of stages and the exact terminology used to define each stage, the overall developmental progression within the English language is agreed upon in the literature and is presented below. The developmental perspective describes children's evolving understanding and application of word structure and print through a series of stages (Beers, 1980; Chomsky, 1979; Gentry, 1978; Pollo et al., 2007; Templeton, 1986). The stages range from early concepts of simple alphabetic symbols to later stages reflecting more interactive application of phonological representations and the English orthographic system (Bourassa & Treiman, 2001; Ehri, 1992; Masterson & Apel, 2000; Masterson & Crede, 1999; Schwartz & Doehring, 1977; Templeton, 1986).

*Stage 1*

During the first stage, referred to as the Preliterate (Henderson, 1990), Prealphabetic (Ehri, 1991), or Precommunicative (Gentry, 1982) stage, theorists believe that children demonstrate the ability to distinguish between drawing and writing (i.e. words), the concept of letters, directionality of print, appearance of spaces between groupings of letters, and basic decoding of phonemes (Beers & Henderson, 1977; Chomsky, 1979; Ehri, 1987; Gentry, 1982; Henderson, 1990; Read, 1975).

*Stage 2*

Progressing from these early skills, children begin to learn about letter names and sounds, which is why this stage is referred to as the Letter-Name, Letter and Sounds, or Semiphonetic stage (Ehri, 1991; Gentry, 1982; Henderson, 1990; Pollo et al., 2007).

During this stage, children regularly misrepresent sound representations using a letter name strategy (Treiman, 1993). For example, they may represent each sound in a target word by a letter or represent a sound within a word using a letter name (e.g., GRL for girl, R for *are*, CR for *car*; Treiman, 1993).

*Stage 3-4*

During the next stage, children begin to produce spellings that reflect more accurate and complete phonological patterns in words (Ehri, 1991; Gentry, 1982; Henderson, 1990; Pollo et al., 2007). For this reason, the stage is referred to as the within-word patterns, full alphabetic, or phonetic stage (Ehri, 1991; Gentry, 1982; Henderson, 1990). Within this stage, children also begin to understand and make use of short and long vowels, meaningful patterns within words (e.g. past tense morphemes such as –ed), and polysyllabic words (Henderson, 1990; Masterson & Crede, 1999; Templeton, 1986).

*Stage 4-5*

The final stages of spelling involve further exploration and understanding of the more subtle and abstract characteristics of English vocabulary (Ehri, 1991; Gentry, 1982; Henderson, 1990). Referred to as the transitional or derivational stage, this phase demonstrates children's more regular application of phonological and orthographic principles leading to accurate word spelling (Bourassa & Treiman, 2001; Ehri, 1992; Masterson & Apel, 2000; Masterson & Crede, 1999; Schwartz & Doehring, 1977; Templeton, 1986; Treiman & Cassar, 1997).

*Implication of Developmental Stages*

As previously stated, the ability to spell words correctly requires a sophisticated understanding and analysis of the English language system. Research studies have identified components of linguistic knowledge critical for word spelling throughout development (Moats, 2005). Consensus within the literature indicates that spelling integrates and depends on the application of letter-sound correspondences, when feasible, and alternative methods for symbolizing spoken words with multiple or irregular spellings (e.g. memorizing orthographic rules, visual memory, knowledge of morphological conventions), which requires higher order cognitive abilities (i.e., executive function; Abbott & Berninger, 1993; Beers, Beers, & Grant, 1977; Berninger, Abbott, Thomson, & Raskind, 2001; Bourassa & Treiman, 2001; Masterson & Apel, 2000; Moats, 1994). While from the developmental perspective these skills seem to emerge in a chronological progression (Bear & Templeton, 1998; Templeton, 2004), research findings suggest that in fact from the beginning stages of spelling development children are learning to coordinate phonological and whole-word retrieval processes simultaneously (Apel & Masterson, 2001; Berninger & Richards, 2002; Carlisle 1994, 1995; Ehri, 1989; Frith & Frith, 1983; Henry, 2003, Nagy, Osborn, Winsor, & O'Flahaven, 1994; Venezky, 1970, 1999). This evidence indicates that both of these linguistic skills are available, to a certain degree, and interact from a young age (Berninger et al., 2006; Pollo et al., 2007; Read, 1986; Seidenberg & McClelland, 1989; Treiman & Cassar, 1997, Treiman et al., 1994). When spelling, children select from phonological and lexical systems and try to apply whichever strategy is appropriate for the situation. Analysis of the errors made when formulating these spellings will potentially determine which strategy a child is or is not using effectively (Apel & Masterson, 2001; Ehri, 1989; Masterson & Crede, 1999; Moats, 1993; Templeton, 2004; Treiman, 2000). Therefore, the presence or absence of phonetic spelling has implications for underlying deficit and treatment.

## *Existing Spelling Assessments*

Since the early 1970's, children's spellings have contributed to our understanding of emerging word knowledge (Beers & Henderson, 1977; Read, 1971, 1975; Templeton, 1979). Read (1971, 1975) conducted some of the first major assessments of children's early spelling attempts. Read found consistent evidence supporting a logical reasoning behind children's spelling patterns, specifically noting the occurrence of phonological strategies in students' spellings. While many studies attempted to emulate and expand upon these findings, many, including Read's, failed to report quantitative data on children's spelling patterns due to the absence of measures designed to assess children's word knowledge through spelling (Ganske, 1999; Treiman et al., 1994; Wasowicz, Masterson, & Apel, 2003). Numerous types of spelling measures exist, but all seem to lack various diagnostic features necessary to accurately portray the complexities of our language system.

### *Spontaneous Writing Tasks*

Spontaneous writing tasks, such as the Writing Processing Test and the Oral and Written Language Scales - Written Expression, offer a natural method for individuals to display their written spelling skills (Carrow-Woolfolk, 1996; Ganske, 1999; Moats, 1994; Warden & Hutchinson, 1992). This process, however, may not accurately reflect a child's spelling competence. The writing process can undermine spelling performance and individuals' written spelling accuracy may vary considerably because of such things as writing topic, motivation to write accurately while composing thoughts, and method of response (i.e. computer vs. handwriting; Moats, 1994). Furthermore, the existing measurements of spelling errors within a written composition are limited to analyzing errors as inaccurate versus accurate and are incrementally more complex than other forms of assessment, if they are to be standardized, in that they require too large a sample of words to be able to realistically capture all possible responses (Carrow-Woolfolk, 1996; Ganske, 1999; Moats, 1994; Warden & Hutchinson, 1992).

*Multiple-Choice Tests*

Multiple-Choice Spelling Recognition tests, such as the Peabody Individual Assessment Test (PIAT), are used to formally assess spelling (Markwardt, 1989; Masterson & Apel, 2000). However, the value of using such a method to assess spelling has been questioned and even, at times, dismissed (Ehri, 2000; Moats, 1995). This type of spelling assessment requires children to select the accurate spelling of a word among four options (Markwardt, 1989). Critics of this type of assessment assert that the task of identifying correct versus incorrect spellings (i.e. proofing) is far different from producing spellings independently (Masterson & Apel, 2000; Moats, 1995).

*Dictated Word Inventories*

Dictated word inventories are a more common form of spelling assessment (Perfetti, 1992; Templeton & Bear, 1992). Many standardized spelling measures use dictated word lists and have been able to quantify spelling performance by scoring responses as accurate versus inaccurate, as done on such widely used spelling measures as the Word Reading Achievement Test (WRAT), Test of Written Language 3rd Edition (TOWL-3), Kaufman Test of Educational Achievement 2nd Edition (KTEA-2), and the Woodcock-Johnson III Tests of Achievement (WJIII-ACH; Hammill & Larsen, 1996; Jastak & Wilkinson, 1984; Kaufman & Kaufman, 2004; Wasowicz et al., 2003; Wilkinson, 1993; Woodcock et al., 2001). Measurement of accuracy versus inaccuracy has provided some insight into the relationship between spelling and reading, as well as children's linguistic knowledge; however, it does not capture some important distinctions in spelling development (Bourassa & Treiman, 2003). Therefore, this method is overly simplistic and severely minimizes the sampling of errors present in the English language (Ganske, 1999; Kroese et al., 2000; Moats, 1994). Both children with and without reading disabilities tend to make spelling errors that are linguistically based (Bourassa & Treiman, 2003). The move from assessment measures that recognize an error to measures that can interpret errors for appropriate instruction has been a difficult and slow process (Ganske, 1999; Kroese et al., 2000).

Dictated spelling tests have the potential to provide an abundance of information, such as identifying stages of development, strength and weaknesses of spelling skills, progress over time, and implications for instructional material (Brown & Loosemore, 1994; Ganske, 1994; Moats, 1993, 1994; Treiman, 2000). However, more complex assessments of spelling errors that attempt to utilize these various aspects seem to lack the technical demands required of good assessment instruments or are based solely on informal subjective, qualitative analysis (Kaufman & Kaufman, 2004; Treiman & Bourassa, 2000a; Vincent & Claydon, 1982; Willows & Scott, 1994; Wilson & Felton, 2004). Others, such as the Diagnostic Spelling Test (DST; Vincent & Claydon, 1982), attempt to incorporate a large number of categories (10-20), within which a limited number of errors exist and are typically not mutually exclusive, making quantitative analysis impractical (Nelson, 1980; Willows & Scott, 1994). In an attempt to classify spelling errors, analyze children's inventive spellings, and to determine patterns of misspellings in children with reading disabilities, many studies have had to produce their own spelling lists that are structured to access specific skills or systematically interpret qualitative patterns of misspellings (Liberman, Rubin, Duques, & Carlisle, 1985; Mann, Tobin, & Wilson, 1987; Treiman & Bourassa, 2000b). What these studies recognize is that spelling is multifaceted, requiring a variety of linguistic skills that emerge in a stage-like progression leading to successful, accurate spelling (Ehri, 1997; Frith, 1980; Gentry, 1982; Henderson, 1990). In an effort to capture the types of spelling errors made, while maintaining methodologically sound scoring protocols, some studies have attempted to dichotomize spelling errors as predictable (phonetic) versus unpredictable (dysphonetic) using standardized dictated spelling lists, such as the Test of Written Spelling 4th Edition (TWS-4) and the Word Identification and Spelling Test (WIST; Larsen, Hammill, & Moats, 1999; Wilson & Felton, 2004). Similarly, many studies have used standardized spelling lists, but have incorporated more stringent scoring criteria for phonetic and dysphonetic spellings in order to reflect advances in the research (Bear et al., 2003; Ganske, 1999; Kessler & Treiman, 2003; Templeton, Bear, & Madura, 2007).

### *Dichotomizing Spelling Errors*

Most research has focused on the qualitatively different processes involved in children's spellings at different points in development and the characteristic progression from stage to stage (Ganske, 1999; Shen & Bear, 2000; Willows & Scott, 1994). Evidence does exist suggesting that the linguistic skills involved in spelling can be both quantifiable and predictive of reading achievement (Ellis, 1997; Masterson & Apel, 2010). This promising finding, in light of the current limitations in existing research, makes the topic of diagnostic spelling a worthwhile research endeavor.

Some researchers have extended the concept of the phonological deficit hypothesis related to reading, which states that individuals compensate for phonological impairments by relying on whole-word retrieval mechanisms (e.g. visual word images, word analogies, and mnemonic rules), to individuals with spelling deficits (Bourassa & Treiman, 2001; Frith, 1985, Stanovich, 1992). Such studies divided spelling errors into phonetic and non-phonetic subtypes or used a scoring system to measure phonetic aspects of spelling words in order to use phonological structure as a determinant of spelling and reading disability. Boder (1973) and Moats (1983) were some of the first researchers to evaluate spellings errors by phonetic accuracy. They both referred to dysphonetic, dyseidetic (i.e. lexical agraphia), and mixed errors presentations, although minimal to no reliability data was provided (Boder, 1973; Moats, 1983). Later studies attempted to elaborate on phonetic classifications using specific sound-letter scaling techniques with established reliability, as well as whole word phonetic/dysphonetic determinations (Finucci, Isaacs, Whitehouse, & Childs, 1983; Invernizzi & Worthy, 1989; Pennington et al., 1986; Stage and Wagner, 1992; Tangel & Blachman, 1992). In general, most of these studies have provided valuable information about spelling ability in clinical populations as well as among their typically functioning peers. What is lacking is the meaningful application of study results for purposes of early identification and instructional strategies.

Ouellette and Senechal (2008) used a spelling scoring system to investigate the relationship between the number of phonemes represented in invented spelling and performance on various cognitive-linguistic skills. Their results, while significant, supported the need for future research regarding the cognitive model of early spelling (Ouellette & Senechal, 2008). Results suggested that additional neurocognitive skills, beyond phoneme awareness and language processes, may be associated with spelling. While there is considerable neuropsychological and neuroanatomical evidence supporting the dual-route systems of spelling and equally robust findings in literacy research supporting the developmental and linguistic nature of phonetic versus dysphonetic misspellings, these two branches of research seem to remain independent and disconnected. The complex neuropsychological and neuroanatomical make up of spelling, as well as its unique visual output, make it a promising data source for informing identification and intervention approaches to reading delay.

## *Statement of the Problem*

Recent controversy in the literature regarding effective and accurate identification methods of Learning Disabilities has inspired the revitalization of Response to Intervention, a method of determining disability and special education eligibility based on failure to respond to more timely and individualized instruction (Fletcher & Denton, 2003; Foorman, Francis, Winikates et al., 1997; Fuchs & Fuchs, 1998; Fuchs et al., 2004; Vaughn & Fuchs, 2003). In order to provide specialized and effective early intervention, which is critical for preventing later reading delays, a comprehensive understanding of the linguistic deficits affecting a child's reading performance is necessary (Fuchs & Fuchs, 2005; Moats, 2005). Reading achievement measures are typically used to assess the major components of reading found to be most predictive of later reading ability and to determine placement and progress in RTI programs (Neuman & Dickinson, 2001; Stanovich, 1986b; Wagner et al., 1994; Whitehurst & Lonigan, 1998). These measures are useful and important assessment tools, however, they are still limited in that they continue to produce false positives and false negatives, and provide minimal instructional implications (Denton et al., 2006; Dickman, 2006; Mathes et al., 2005; O'Connor, 2000; Speece et al., 2003).

The contribution of spelling to our understanding of emerging word knowledge has been demonstrated in both intervention and measurement studies (Berninger, Abbott, Abbott, et al., 2002; Ehri & Wilce, 1982; Griffith, 1991; Santoro, et al., 2006; Wanzek, et al., 2006). Research demonstrating the interrelationship between reading and spelling, coupled with theories and evidence-based research regarding the linguistic and neuropsychological nature of misspellings suggests that analyses of children's early spelling attempts may capture their understanding of how to decode text (Bear & Templeton, 1998; Ehri, 1989; Perfetti, 1997; Treiman & Bourassa, 2000b). However, current spelling measures do not adequately assess the complexity of the linguistic and neurodevelopmental processes represented by early spelling attempts (Masterson & Apel, 2000; Masterson & Crede, 1999; Moats, 2005; Treiman & Bourassa, 2000b; Willows & Scott, 1994; Wilson & Felton, 2004). Because spelling involves the integration of multiple cognitive processes and provides an independent visual product of how a child processes linguistic information, dichotomizing spelling errors may reveal subtle differences in neurocognitive functioning, distinguishing between struggling readers with and without language deficits. According to the phonological deficit hypothesis and neurocorrelates associated with the dual-route model for spelling, children with language-based difficulties would be expected to produce a lower proportion of phonetically equivalent misspellings, whereas children with executive function difficulties would be expected to produce a higher proportion of phonetically equivalent misspellings (Bourassa & Treiman, 2003; Bruck & Waters, 1988; Fox & Routh, 1983, Moats, 1993). Therefore, a quantitative analysis of the phonetic equivalence in spelling errors may reveal neurocognitive deficits underlying language processes and prove to establish greater insight into children's understanding of the language system, above and beyond current reading measures.

The proposed study explored the application of a system for analyzing spelling errors to determine its relationships with functioning in the areas of language and executive function. The purpose of this study was to validate whether phonetic versus dysphonetic misspellings could be explained by neurocognitive deficits in language and executive function and, if so, the extent to which they each provided additional information regarding reading performance. By investigating the relationship between spelling errors and neurocognitive fucntioning, this study sought to aid in the prediction of reading achievement of students at risk of reading failure and contribute to explanation of "unexpected" underachievement. This new approach to identifying reading deficits has the potential to inform future methods for reading intervention and may be useful in creating more effective reading intervention programs that are more closely linked to areas of deficit.

## *Research Questions and Hypotheses*

### *Research Question 1*

Do measures of language ability, including the California Verbal Learning Test – Children's Version (CVLT-C) Long Delay Free Recall subtest, Woodcock-Johnson III Tests of Achievement (WJ III-ACH) Letter-Word Identification and Word Attack subtests, and Wechsler's Intelligence Scale for Children – Fourth Edition (WISC-IV) Vocabulary subtest, predict dysphonetic misspellings, above and beyond age and gender, among children at risk of reading delay?

### *Hypothesis 1*

There will be a positive relationship between phonetic equivalency scores and performance on measures of language ability, controlling for age and gender.

*Rationale*

Considerable evidence exists documenting the relationship between language-based deficits and spelling performance (Ouellette & Senechal, 2008; Savage & Frederickson, 2006). According to the phonological core deficit model, children with linguistic skill deficits experience significantly greater difficulty with sound-symbol correspondences, thus impeding their ability to discriminate sounds in order to spell words according to their phonetic equivalents. Therefore, dysfunctions in the phonological pathway result in phonetically incorrect or dysphonetic spellings.

*Research Question 2*

Do measures of Executive Function, including the WISC-IV Processing Speed and Working Memory Index scores and the Behavior Rating Inventory of Executive Function (BRIEF) Metacognition Index, predict phonetic misspellings, above and beyond age, gender, and language ability, among children at risk of reading delay?

*Hypothesis 2*

There will be a negative relationship between phonetic equivalency scores and performance on measures of executive function, controlling for age, gender, and language ability.

*Rationale*

There exist robust findings suggesting that neurocognitive factors associated with executive function, specifically metacognitive abilities, contribute to difficulties in spelling performance as well (Frazier et al, 2004; Marzocchi et al, 2008; Reiter et al, 2005). The dual-route model postulates that impairment of executive functioning hinders the whole-word retrieval process, which requires the application of lexical memory and problem solving to translate language to print. Therefore, executive dysfunction contributes to impairment of the lexical pathway, resulting in highly phonetic misspellings due to an over-reliance on phonological or language processes.

# Chapter III: Method

## *Participants*

Participants were selected from the assessment files of Austin Neuropsychology Clinic patients who were referred for comprehensive neuropsychological evaluations between 2009 and 2011. Data were collected from the existing records of 82 children who met criteria for one of two diagnostic groups: Attention-Deficit/Hyperactivity Disorder or Reading Deficit. The participants' ages ranged from 6 to 15 years (see Table 1 for distribution) with males outnumbering females by 34.2 percent (see Table 2 for distribution). The sample was primarily Caucasian (see Table 3 for distribution).

Table 1

*Distribution of Participants by Age*

| Age of participants | Percentage of sample |
|---|---|
| 6 | 7.3% |
| 7 | 19.5% |
| 8 | 8.5% |
| 9 | 19.5% |
| 10 | 11.0% |
| 11 | 4.9% |
| 12 | 8.5% |
| 13 | 6.1% |
| 14 | 8.5% |
| 15 | 6.1% |

Table 2

*Distribution of Participants by Gender*

| Gender of Participants | Percentage of Sample |
|---|---|
| Male | 67.1% |
| Female | 32.9% |

Table 3

*Distribution of Participants by Race*

| Racial Group of Participants | Percentage of Sample |
|---|---|
| Caucasian | 85.4% |
| Latino | 9.8% |
| Bi-racial/Multi-racial | 3.7% |
| African American | 1.2% |

*Inclusionary Criteria*

Prior to testing and prior to the onset of this study, written consent was obtained in order to use the child's testing records for research purposes (Appendix A). Children and parents were made aware that a release of records for research purposes was voluntary and that the participant could withdraw consent at any time without repercussions.

Files chosen for the ADHD group included participants who met criteria for ADHD according to standards set forth by the Diagnostic and Statistical Manual of Mental Disorder, 4th Edition- Text Revision (DSM-IV-TR), as assessed by the Swanson, Nolan, and Pelham Questionnaire Rating Scale (SNAP-IV; Swanson, 1992) and information collected from the parent clinical interview. Files of children who demonstrated a predominant symptom type of inattention (ADHD, Predominantly Inattention Type) or hyperactivity (ADHD, Predominantly Hyperactive-Impulsive Type), or both (ADHD, Combined Type), on parent or teacher questionnaires, and as determined by the neuropsychologist of record, were selected. Files chosen for the Reading Deficit group included participants who performed below the 26th percentile, which is less than or equal to a standard score of 90, on the Woodcock-Johnson III Tests of Achievement Letter-Word Identification or Word Attack subtests. Such reading decoding scales are frequently used as a norm-referenced assessment to determine risk for reading difficulties (Mahony, Singson, & Mann, 2000). Furthermore, performance below the 26th percentile on these scales represents current standards for identifying reading difficulties and placement in RTI programs (Bental & Tirosh, 2007; Chiappe, Chiappe, & Gottardo, 2004; Mahony et al., 2000, Snow, Burns, & Griffin, 1998). Within the Reading Deficit group, 18 participants had lower scores on the WA subtest than LWID subtest. Of these 18 cases, five had both WA and LWID scores equal to or below 90 and 13 had LWID scores above 90 and WA equal to or below 90. Nineteen participants had lower scores on the LWID subtest than WA subtest. Of these 19 cases, seven had both WA and LWID scores equal to or below 90 and 12 participants scored above 90 on WA and equal to or below 90 on LWID. The remaining one participant had equal scores on both measures.

Data were collected from Reading Deficit and ADHD populations given their increased incidence of reading delays and for purposes of capturing various neurocognitive factors contributing to reading difficulties. As such, approximately equal group sizes were chosen in order to adequately represent the heterogeneity of their neurocognitive profiles (See Table 4 for distributions). Of the 40 participants in the Reading Deficit group, 30 participants had comorbid ADHD diagnoses. Given the high prevalence of comorbidity within these two populations, participants with dual diagnoses of Reading Deficit and ADHD were not excluded. Additionally, the goal of the study was to capture a sample of children who typically demonstrate reading difficulties within the general population, of which Reading Disorder and ADHD populations account for a substantial number. Comorbidity was not excluded because the study was also intended to capture variability in language and executive function deficits affecting linguistic-based difficulties, symptoms both of these populations demonstrate to varying degrees regardless of their co-occurrence.

All participants had a measured Full Scale Intelligence Quotient (FSIQ) of 85 or higher on the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003). Additionally, all participants had hearing and vision within the normal range, or corrected to be within the normal range. Only children with English as the primary language were included.

Table 4

*Distribution of Participants by Group Type*

| Group | Percentage of Sample |
|---|---|
| Attention-Deficit/Hyperactivity Disorder (ADHD) | 51.2% |
| Reading Deficit (RD) | 48.8% |

*Exclusionary Criteria*

In accordance with the definition and classification of a Learning Disability, children who were identified as having sensory impairments, mental retardation, or emotional disturbance were not included in this study. Furthermore, because of the documented effect oral language proficiency has on reading acquisition and achievement, students not proficient in English (i.e. English Language Learners) were excluded from the study (Fitzgerald, 1995; Fitzgerald & Noblit, 2000; Geva, 2000; Snow et al., 1998; Wong-Fillmore & Valadez, 1986). Children who participated in school-based reading intervention programs or after-school programs using scientifically-based reading interventions, as defined by the What Works Clearinghouse (WWC) Evidence Standards from the U.S. Department of Education's Institute of Educational Sciences (n.d.), were excluded due to the potential remediation effects on psychodiagnostic and neuropsychological measures. Children with a positive history of epilepsy, traumatic brain injury, or progressive neurological disorder, as indicated on a structured developmental and family data form (Appendix B), were also excluded from this study.

## *Instrumentation*

*Woodcock-Johnson III Tests of Achievement (WJ III-ACH; Woodcock et al., 2001)*

The WJ III-ACH is an individually administered standardized assessment. It contains 22 tests measuring five curricular areas – reading, math, written language, oral language, and academic knowledge. For the purpose of this study, data for the Letter-Word Identification and Word Attack subtests, as well as the Basic Reading Skills cluster, were collected. The spelling subtest was also collected, although alternate scoring procedures were implemented and are described in the following section (See Procedure). Letter-Word Identification measures aspects of reading decoding by requiring examinees to identify and pronounce isolated letters and words. Scores on this subtest have a median reliability of .91 in the age range of 5 to 19. Word Attack measures aspects of phonological and orthographic coding by requiring examinees to apply phonic and structural analysis skills in pronouncing phonically regular nonsense words. Scores on this subtest have a median reliability score of .87 in the age range of 5 to 19. The Basic Reading Skills cluster score is frequently used as a norm-referenced assessment to determine risk for reading difficulties and placement in RTI programs (Mahony et al., 2000). It is an aggregate measure of sight vocabulary, phonics, and structural analysis, derived from performances on the Letter-Word Identification and Word Attack subtests. The scores on this cluster have a median reliability of .93 in the age 5 to 19 range. Spelling measures aspects of phoneme/grapheme knowledge by requiring examinees to spell dictated words. Scores on this subtest have a median reliability score of .90 in the age 5 to 19 range.

The WJ III-ACH was normed with a sample selected to represent the U.S. population from ages 24 months to 90+ years. Normative data for the test were gathered from 8,818 subjects over 100 geographically diverse communities in the United States. Individuals were randomly selected within the stratified sampling design that controlled for 10 specific community and individual variables and 13 socioeconomic status variables. The WJ III-ACH is a highly accurate and valid diagnostic system. The reliability characteristics meet or exceed basic standards for both individual placement and programming decisions (Mahony et al., 2000; Woodcock et al., 2001).

*Wechsler's Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003)*

The WISC-IV is a battery of individually administered tests designed to provide a comprehensive measure of general cognitive functioning for children 6-16 years of age. The WISC-IV provides a Full Scale IQ (FSIQ), as well as groups an individual's ability into four global areas or index scores: Verbal Comprehension (VCI), Perceptual Reasoning (PRI), Working Memory (WMI), and Processing Speed (PSI). For the purpose of this study, the Working Memory and Processing Speed indices were examined, although the FSIQ was used to determine participants' overall cognitive ability and eligibility for the study. The Working Memory Index and Processing Speed Index were used to assess the working memory and speed of processing aspects of executive function, which are shown in the literature to be areas of marked deficit among children with reading deficits (Baron, 2004; McCallum et al., 2006; Ouellette & Senechal, 2008;

Rucklidge & Tannock, 2002). The Vocabulary subtest was used to assess lexical knowledge component of language ability.

FSIQ reliability estimates for the standardization sample were excellent with internal consistency coefficients ranging from 0.96-0.97 and test-retest reliability coefficients greater than or equal to 0.91 for each age group (Wechsler, 2003). Internal consistency coefficients were greater than 0.90 and 0.80 for scores on the WMI and PSI, respectively. The Vocabulary subtest measures aspects of language and lexical knowledge by requiring examinees to name pictures or provide definitions of words. Scores on this subtest have a mean reliability of .89 across age groups.

The WISC-IV was normed with a sample selected to represent the U.S. population from ages 6:0 to 16:11 years. Normative data for the test were gathered from 2,200 subjects matched closely to represent diverse communities in the United States, according to data from the 2002 U.S. Census, on variables of age, gender, geographic region, ethnicity, and socioeconomic status. Individuals were randomly selected within the stratified sampling design that controlled for 11 age groups, each composed of 200 children. The WISC-IV is a highly accurate and valid diagnostic system. The reliability characteristics meet or exceed basic standards for both individual placement and programming decisions (Wechsler, 2003).

*Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000)*

The BRIEF is an individually administered, 86-item questionnaire designed to assess the executive functioning of school-aged children within the home and school environments. It consists of two rating forms, parent and teacher, which provide standardized observational reports of everyday functioning. For the purpose of this study, information from the parent form was used in order to obtain an estimate of the participants' overall executive functioning, as perceived by a primary guardian. The BRIEF provides evaluative information for children ages 5 to 18 years with a variety of developmental, neurological, psychiatric, and medical conditions, such as learning disabilities and attentional disorders, traumatic brain injury, pervasive developmental disorder, and Tourette's disorder. The BRIEF questionnaire is scored using eight clinical scales and two validity scales, which comprise two broad Indexes (Behavioral Regulation Index and Metacognition Index), as well as a Global Executive Composite score. The Metacognition Index score was reported for this study to serve as a measure of cognitive based executive functions (i.e. cold executive function), such as those associated with working memory, organization and planning, and attention.

The BRIEF was standardized using normative data based on child ratings from 1,419 parents, representing diverse populations reflecting the 1999 U.S. Census estimates for socioeconomic status, ethnicity, and gender distribution. The sample consisted of males and females with no history of special education or psychotropic medication usage, as well as included a clinical sample with developmental disorders or acquired neurological disorders. Reliability estimates of scores on the BRIEF for the standardization sample were high, with internal consistency coefficients ranging from 0.80-0.98 and test-retest reliability coefficients greater than or equal to 0.82 for parent ratings (Gioia et al., 2000). Multitrait-multimethod matrix was used to examine convergent and discriminant validity of the BRIEF compared with other measures, indicating that scores on the BRIEF correlated with scores on other tests of inattention, impulsivity, and learning skills. Conversely, scores on the BRIEF correlated less strongly or not at all with scores on measures of emotional functioning. Reliability and validity data indicate that the BRIEF is a highly accurate and valid diagnostic rating system (Baron, 2004; Gioia et al., 2000).

*California Verbal Learning Test – Children's Version (CVLT-C; Delis, Kramer, Kaplan, & Ober, 1994)*

The CVLT-C is an individually administered test of verbal learning and memory for children ages 5-0 to 16-11. It is comprised of multiple trials designed to measure memory acquisition, retention, retrieval, and interference effect, as well as the ability to organize and retrieve information from memory according to phonological and semantic features of words. Children are provided with a 15-word target list composed of five words from each of three semantic categories, from which they are asked to verbally recall words in any order. For the purpose of this study, scores from the long delay free recall subtest were recorded in order to access performance patterns in retrieval of verbal information, which has been linked to phonological processing and lexical-semantic knowledge (Baron, 2004; Nadeau, 2003). Additionally, several studies have investigated the relationships of CVLT performance and executive function ability (Beebe, Ris, & Dietrich, 2000; Tremont, Halpert, Javorsky, & Stern, 2000; Vanderploeg, Schinka, & Retzlaff, 1994). Such studies reported results suggesting that memory retention (i.e. delayed recall) was not affected by executive dysfunction, making the CVLT long delay free recall a good instrument for measuring language ability, as affected by new verbal learning and verbal memory.

The CVLT-C normative data were derived from a standardization sample of 920 children based on the 1988 U.S. Census survey data (Spreen & Strauss, 1998). Using a stratified random sampling plan, children were selected to ensure a representative proportion from the following demographic groups: age, gender, race/ethnicity, geographic region, and parent education level. The authors reported moderate to high estimates of internal consistency for across-trial consistency, ranging from 0.81 to 0.91, and for across-word consistency, ranging from 0.81 to 0.83. Test-retest reliability correlations ranged from 0.38 to 0.90 for 8 year olds, 0.17 to 0.77 for 12 year olds, and 0.31 to 0.85 for 16 year olds. Test-retest reliability correlations for the Long-Delay Free Recall scale were equal to 0.69, 0.62, and 0.60 for children aged 8, 12, and 16, respectively. The results of factor analysis, using varimax rotated factor structure, found 6 factors for 19 CVLT-C indices (Delis et al., 1994; Spreen & Strauss, 1998). Several follow up studies found comparable factor structures in typically functioning populations, as well as neurological and severe head injury populations. Correlations between the CVLT-C and other standard measures of learning and memory, including the Wechsler Memory Scale, Selective Reminding Test, and Recognition Memory Test, also indicate moderate results and suggest that the CVLT is a valid diagnostic measure (Delis et al., 1994).

## *Procedure*

### *Project Approval*

The proposed study complies with the ethical principles and standards of research set forth by the American Psychological Association and the Procedures Governing Research with Human Subjects at Austin Neuropsychology Clinic. Approval for this study was given by the Departmental Review Committee in the Department of Educational Psychology and the Institutional Review Board for the Protection of Human Subjects at the University of Texas at Austin (IRB Approval Protocol # 2010-02-0127).

### *Data Collection*

Data were collected from existing assessment files of patients from Austin Neuropsychology Clinic who were referred for comprehensive evaluations between 2009 and 2011. See Appendix C for details about the assessment process and procedures at Austin Neuropsychology Clinic. Files chosen for this study were based on the inclusionary and exclusionary group criteria described above.

Each participant completed and received scores on the following scales as a part of the more comprehensive battery: Wechsler Intelligence Tests for Children, Fourth Edition (WISC-IV) Processing Speed and Working Memory indices and Vocabulary subtest, Woodcock-Johnson III Tests of Achievement (WJ III-ACH) Letter-Word Identification and Word Attack subtests, California Verbal Learning Test-Children's Version (CVLT-C) Long Delay Free Recall trial, and the Behavior Rating Inventory of Executive Function (BRIEF) Metacognition Index score. These scores serve as independent variables and were entered into PASW Statistics 18.0. An additional variable, Phonemic Equivalency Score (PES), was created as the dependent variable and is described in the following section. The results on aspects of these tests were used to assess the unique contribution of executive functioning and language ability to the phonemic equivalency of spelling errors.

*Creation of the Phonemic Equivalency Score (PES)*

*Phoneme analysis*. A PES score was derived from the Spelling subtest of the WJ III-ACH. Phonetic analysis of spelling involves totaling letters or word parts (phonemes) that are plausible phonetic equivalents of the phonemes of the target word they represent (Bourassa & Treiman, 2003). Additionally, the analysis takes into account the articulation and speech production of the whole word and the effect it may have on its spelling representation (e.g., GRL for girl, R for *are*, CR for *car*, past tense morpheme "ed" is pronounced /d/, /t/, or /ed/, and could be reflected as such in misspellings). Dividing misspellings into phonetic versus dysphonetic at the phoneme level requires the analysis of each letter or letter group used to symbolize the sound part of the target word in English. An error is phonetic when a phoneme of the target word is represented in a spelling attempt. An error is dysphonetic when a phoneme is either omitted or incorrectly symbolized (e.g. "sik" for "sink" or "fab" for "fad").

Students' spelling was examined to identify which words were spelled incorrectly. A phonemic equivalency score was derived using the methodology reported by Friend and Olson (2008). Specifically, for each misspelled word the number of phonetically accurate phonemes represented in order was summed. Additionally, the total number of phonemes present in the conventional spelling of each target word was summed. In order to restrict phonemic interpretations, words were also divided into syllables based on the syllable divisions presented in *Merriam-Webster's Dictionary Online*. If it was difficult to determine where to make the syllable division due to ambiguity of the misspelling, the word was divided as to maximize the accuracy of the phoneme within each syllable. The PES was then calculated by dividing the total phonetically accurate phonemes represented in order for all misspellings by the total number of phonemes present in the conventional spelling of all target words.

The following is a case example of an individual spelling item: One child in the current study spelled the word *under* as "udr." The conventional spelling of the word was divided into two syllables (*un-der)* and the total number of phonemes present were represented and summed (∂/n/d/∂r, where ∂ = schwa sound) to equal 4. The number of accurate phonemes in the child's spelling approximation was also summed (∂/d/∂r) to equal 3 sound representations. Therefore, this individual represented 3 out the 4 phonemes in the conventional spelling of the target word (75% correct for this one word). Although this child's spelling was incorrect, the child accurately identified several phonological structures of the word.

*Reliability*. To estimate scoring objectivity and to ensure consistency of ratings across judges, the methodology reported by Tangel and Blachman (1995) and Treiman and Bourassa (2000a) was utilized. This procedure requires that two raters independently score all spelling attempts. Rater 1, the author, and Rater 2, a graduate student, were doctoral students in school and counseling psychology, respectively, with no direct training in analyzing sounds in words, but possess adequate linguistic knowledge and extensive experience in the assessment of reading disabled students. Raters reviewed the criteria for the PES system prior to data collection and scoring, and were provided with a scoring rubric as a reference guide. Inter-rater reliability was considered in two ways. First, the percentage agreement between the two raters on all items was calculated, which was 82.9%. Second, inter-rater reliability was also assessed by calculating Pearson correlation coefficients between the total score given to each child by the two raters. The correlation of rater's scores was $r = .994$, which indicates good inter-rater reliability. Inconsistencies were present on 14 cases, which were reviewed and discussed by the raters. Subsequently, a consensus score was decided upon.

# Chapter IV: Results and Analyses

This chapter presents the results of the analysis of the data. The findings include the general trends of the data for the final sample, as well as results specific to each of the research questions. Supplementary exploratory analyses were also conducted on each diagnostic group, ADHD and RD. All analyses were performed using PASW Statistics 18.0 (released in 2009).

## *Preliminary Data Analysis*

### *Power Analysis*

An a priori power analysis was conducted using the G*POWER 3 program software to determine the appropriate sample size necessary to detect a statistically significant effect if one exists (Faul, Erdfelder, Lang, & Buchner, 2007). In multiple regression, it is especially important to determine how many subjects will be needed, given certain input parameters, for the development of a reliable prediction equation that has generalizability. G*POWER 3 program software was used to determine the sample size needed in the current study that would result in at least .80 power, with alpha = .05 and with a medium effect size (Cohen's $f^2$=.15), which is considered more than sufficient for social science research when using multiple regression (Cohen, 1988; Keith, 2006; Stevens, 1999). Using a regression equation with 7 predictors, Power Analysis showed that a minimum sample size of 55 was required for this study.

Power was also analyzed following data collection using all eligible files according to inclusionary and exclusionary criteria previously reported. Using a medium effect size (Cohen's $f^2$=.15), alpha = .05, with a sample size of 80 and an overall regression with 9 predictors, the power for this study was .82.

*Descriptive Statistics*

Descriptive statistics for all variables are presented in Table 5, with values rounded to the nearest hundredth. To examine the relationship between pairs of predictor variables, intercorrelations among the independent variables were calculated and reported in Table 6. The descriptive output was used to examine means, standard deviations, and minimum and maximum values for each variable in order to check for proper data entry and help determine if errors were present.

Table 5

*Mean, Standard Deviation, and Range for Key Variables for Total Sample*

| Variables | M | SD | Range |
|---|---|---|---|
| Age in months | 122.93 | 31.85 | 77-189 |
| California Verbal Learning Test – Children's Version (CVLT)[a] | .10 | 1.06 | -2.5-2.0 |
| Vocabulary[b] | 11.00 | 2.49 | 5-17 |
| Letter-Word Identification (LWID)[c] | 96.98 | 11.12 | 60-119 |
| Word Attack (WA)[c] | 97.15 | 9.71 | 71-128 |
| Metacognition Index (MCI)[d] | 36.83 | 10.56 | 18-63 |
| Working Memory Index (WMI)[c] | 94.80 | 12.49 | 71-135 |
| Processing Speed Index (PSI)[c] | 93.11 | 12.54 | 65-118 |
| Phonemic Equivalency Score (PES)[e] | 86.98 | 12.01 | 50-100 |

[a]z-scores with mean of 0. [b]Scaled scores with mean of 10. [c]Standard scores with mean of 100. [d]T-scores with mean of 50. [e]Percentile ranks.

Table 6

*Intercorrelations Between Independent and Dependent Variables*

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Age | 1.00 | | | | | | | | |
| 2. CVLT | .172 | 1.00 | | | | | | | |
| 3. Vocab | .214 | .330** | 1.00 | | | | | | |
| 4. LWID | .089 | .261 | .373** | 1.00 | | | | | |
| 5. WA | -.123 | .150 | .247 | .697** | 1.00 | | | | |
| 6. MCI | -.131 | -.088 | -.092 | -.349** | -.230 | 1.00 | | | |
| 7. WMI | .186 | .245* | .458** | .541** | .535** | -.090 | 1.00 | | |
| 8. PSI | -.058 | .180 | .142 | .245 | .207 | .054 | .188 | 1.00 | |
| 9. PES | .462** | .283** | .208 | .574** | .387** | -.196 | .446** | .044 | 1.00 |

*Note:* CVLT = California Verbal Learning Task – Children's Version; Vocab = Vocabulary; LWID = Letter-Word Identification; WA = Word Attack; MCI = Metacognition Index; WMI = Working Memory Index; PSI = Processing Speed Index; PES = Phonemic Equivalency Score. **$p < .01$.

*Missing Data and Outliers*

The data were examined prior to conducting analyses to ensure that results were not unduly affected by missing values. Of the 82 participants, two cases had missing data on the Word Attack variable. This study used archival data; therefore, it was not possible to retrieve missing data. Listwise deletion was used to address missing data for all analyses involving the Word Attack variable. Exploratory analyses not involving this variable utilized the full sample size of 82. Power for these exploratory analyses was .83.

Outliers are scores observed to deviate from the normal range of values you would expect for a particular variable. It may indicate a sample peculiarity, data entry error, or other problem. If outliers are present, the mean for a set of data may not be an accurate representation of these data and the distribution may in effect be non-symmetrical or skewed, leading to inaccurate interpretation. Data were screened for outliers due to the effect on multivariate normality. Outliers were defined as scores greater than 3 standard deviations from the mean score. Histograms were used to visually analyze the distribution of each independent variable in order to detect outliers or data points that present extreme or atypical values compared to the distribution. No outliers were detected. A histogram of the dependent variable was also examined. One outlier was detected among the dependent data set. The outlier within the PES score was -3.33 standard deviations from the mean score. Upon review of the raw score, it was deemed appropriate to remove the participant from the dataset due to inaccurate administration of the WJ Spelling measure. Specifically, the basal criteria (i.e., minimum items administered) for the subtest was not fulfilled, resulting in a phonemic equivalency score derived from two spelling items rather than a minimum of six. Analyses were run with this case deleted and using the resulting distribution.

*Assumptions of Multiple Regression*

Regression procedures have certain assumptions that must be met in order to accurately analyze data (Miles & Shevlin, 2001). Therefore, preliminary analyses were conducted to examine for violations of the assumptions of multiple regression. Three of the assumptions, linear relationship between the predictor and the criterion, multivariate normal distribution, and homoscedasticity, were assessed by analyzing the residuals (i.e. estimated errors). Examination of the scatter plot of the residuals versus predicted values suggested that the assumptions of homoscedasticity and linearity were met. Slight truncation was observed as the predicted value of the outcome variable increased, indicating some potential heteroscedasticity; however, it was not significant enough to warrant exclusion. The histogram and normal probability plots were also examined for multivariate normality and indicated normally distributed residuals.

The Durbin-Watson statistic was used to assess the assumption for independence of residuals. This test revealed a value of 2.08, suggesting that no autocorrelation is present in the residuals. Multiple regression also assumes singularity, meaning predictor variables cannot be combinations of other predictor variables. Measures and subtests were specifically chosen to meet this criterion. All predictor variables are mean scores from independently derived subtests.

Lastly, multiple regression assumes the absence of multicollinearity (i.e. the intercorrelation of two or more predictors). Intercorrelations among independent variables were reported above in a correlation matrix. In examining the bivariate correlations in Table 6, a number of statistically significant relationships emerged. However, this figure does not determine whether collinearity is problematic. Therefore, multicollinearity between the predictors was assessed using the tolerance and variance inflation factor (VIF). The tolerance statistic is an indication of the percent of variance in the predictor that cannot be accounted for by other predictors. Values less than .10 indicate that a predictor is redundant. The tolerance values for the predictors ranged from

.36 to .99, indicating all values are acceptable. The VIF value, which is the inverse of tolerance (1/tolerance), ranged from 1.00 to 2.81. VIF values greater than 10 are considered redundant, indicating multicollinearity is likely not problematic (Miles & Shelvin, 2001; Tabachnick & Fidell, 2006).

## *Main Analyses*

### *Test of Hypotheses*

Regression analysis procedures were used to determine the extent to which language and executive functioning can be attributed to the phonemic equivalency of spelling errors. Hypotheses were tested using Hierarchical Multiple Regression (Mertler & Vannatta, 2005), which uses a nested models approach to evaluate the unique contribution of block(s) of independent variables. Selection of variables and order of entry were determined by the hypotheses of interest and based on theory. In order to control for the effects of age and gender, the first step of the hierarchical analysis included a model looking at the amount of variability in the PES outcome variable explained by age and gender. The regression of age and gender on PES represents the baseline model (Model 1 in Table 7). When age and gender were entered alone, they together explained a significantly amount of variability in the level of phonemic equivalency [$F$ (2, 77) = 17.54, $p$ = <.001, adjusted $R^2$ = .30]. The baseline model accounted for 30% of the variance in the PES, as indicated by the value of the adjusted $R^2$.

*Hypothesis 1*

Hypothesis 1 predicted that there would be a positive relationship between phonetic equivalency scores and language, controlling for gender and age. To determine the unique contribution of language to the variance in the dependent variable, the four measures of language – CVLT delayed recall, WJ LWID, WJ Word Attack, and WISC Vocab – were added as a single block (Model 2 in Table 7). When the language variables were added, there was a statistically significant increase in the variance accounted for from model 1 to model 2 [$R^2$ change = .25, $F(4, 73) = 10.33$, $p < .001$], suggesting that the block of four language subtests increased the variance explained in the outcome, over and above that accounted for by age and gender. The entire group of variables in model 2 (Table 7), including age, gender, and language measures, significantly predicted the PES [$F(6, 73) = 15.57$, $p < .001$, adjusted $R^2 = .53$].

*Hypothesis 2*

Hypothesis 2 predicted that there would be a negative relationship between phonetic equivalency scores and executive function, controlling for gender, age, and language. To determine the unique contribution of executive function to the variance in the dependent variable, the four measures of executive function – WISC-PSI, WISC-WMI, BRIEF-MCI – were added as a single block (Model 3 in Table 7). The addition of the block of three executive function variables did not result in a significant change in variance accounted for from model 2 to model 3 [$R^2$ change = .03, $F(3, 70) = 1.39$, $p >$ .001]. The executive function subtests did not account for a significant amount of variability in the PES outcome measure, above and beyond that explained by gender, age, and language. Although the linear relationship of executive function and phonemic equivalency did not account for a significant increase in $R^2$, the test of the full model (Model 3 in Table 7), which includes the entire group of variables, significantly predicted the PES [$F(9, 70) = 11.01$, $p < .001$, adjusted $R^2 = .53$].

Table 7

*Hierarchical Regression Analysis for Variables Predicting Phonemic Equivalency Score*

| Model | $R^2$ | Adjusted $R^2$ | $R^2$ Change | F | F Change |
|---|---|---|---|---|---|
| Model 1 | .31 | .30 | .31 | 17.54** | 17.54** |
| Model 2 | .56 | .53 | .25 | 10.33** | 10.33** |
| Model 3 | .59 | .53 | .03 | 11.01** | 1.39 |

*Note:* Model 1 = Age, Gender; Model 2 = Age, Gender, California Verbal Learning Test – Children's Edition, Vocabulary, Letter-Word Identification, Word Attack; Model 3 = Age, Gender, California Verbal Learning Test – Children's Edition, Vocabulary, Letter-Word Identification, Word Attack, Working Memory Index, Processing Speed Index, Metacognition Index

**p < .001.

Table 8

*Summary of Hierarchical Regression Coefficients for Variables Predicting Phonemic Equivalency Score*

| Model | Unstandardized Coefficients | | Standardized Coefficients |
|---|---|---|---|
| | B | *SE* B | β |
| Model 1 | | | |
| Age | .19 | .04 | .48** |
| Gender | 7.23 | 2.44 | .28** |
| Model 2 | | | |
| Age | .19 | .03 | .47** |
| Gender | 3.02 | 2.2 | .12 |
| California Verbal Learning Test | 1.11 | .96 | .10 |
| Vocabulary | -.57 | .43 | -.12 |
| Letter-Word Identification | .44 | .13 | .40** |
| Word Attack | .21 | .14 | .16 |
| Model 3 | | | |
| Age | .18 | .03 | .45** |
| Gender | 3.96 | 2.20 | .15 |
| California Verbal Learning Test | 1.17 | .96 | .10 |
| Vocabulary | -.74 | .45 | -.15 |
| Letter-Word Identification | .43 | .14 | .40** |
| Word Attack | .15 | .15 | .12 |
| Working Memory Index | .15 | .10 | .16 |
| Processing Speed Index | -.12 | .08 | -.11 |
| Metacognition Index | .06 | .20 | .05 |

**$p < .001$.

### *Summary of Main Analyses*

The main analyses examined the effects of age, gender, language, and executive functioning on the phonemic equivalency of spelling errors. The Hierarchical Regression analysis revealed that age and gender significantly predicted PES performance. When language variables were added, they significantly improved the prediction. Measures of executive function did not significantly contribute to the variability in the PES measure, above and beyond that explained by gender, age, and language

## *Supplemental Exploratory Data Analyses*

### *Effects of Individual Predictors on the Phonemic Equivalency Score*

For the purpose of determining the implications of this research for future research and practice, unstandardized regression coefficients for individual predictors in the full model, as well as their corresponding level of significance, were examined. These values indicate the relative contribution of each predictor variable, in the presence of all other subtests, in explaining the variability in phonemic equivalency scores. The unstandardized regression coefficients, presented in Table 8, suggest that age and Letter-Word ID were the only coefficients that significantly contributed to the prediction of the outcome variable when considering all variables together. Age accounted for .45 ($p <$ .001) of the total variance in the PES and Letter-Word ID accounted for .40 ($p < .001$).

### *Group Differences on the Phonemic Equivalency Score*

To further understand the significant associations present in the main regression analysis, a one-way ANOVA (independent samples t-test) was used to evaluate the statistical significance of group difference. Specifically, differences on the PES dependent variable were examined between the ADHD and RD groups. Descriptive statistics for all variables by group are presented in Table 9, with values rounded to the nearest hundredth. Tests on the dependent variable indicated that the groups differed in their PES scores [$F$ (1, 80) = 32.48, $p$ < .001].

Table 9

*Mean, Standard Deviation, and Range for Key Variables by Group*

| | Reading Deficit (n = 38) | | | ADHD (n = 42) | | |
|---|---|---|---|---|---|---|
| Variables | M | SD | Range | M | SD | Range |
| Age in months | 124.73 | 34.55 | 79-198 | 121.21 | 29.37 | 77-183 |
| CVLT[a] | -0.15 | 1.05 | -2.5-2.0 | 0.35 | 1.03 | -2.0-2.0 |
| Vocab[b] | 10.43 | 2.57 | 5-17 | 11.55 | 2.32 | 6-16 |
| LWID[c] | 88.43 | 7.12 | 60-104 | 105.12 | 7.55 | 92-119 |
| WA[c] | 90.05 | 5.12 | 71-102 | 103.57 | 8.32 | 91-128 |
| MCI[d] | 40.05 | 11.66 | 18-63 | 33.76 | 8.43 | 19-61 |
| WMI[c] | 88.63 | 11.37 | 71-116 | 100.69 | 10.61 | 86-135 |
| PSI[c] | 91.05 | 12.38 | 68-115 | 95.07 | 12.53 | 65-118 |
| PES[e] | 80.41 | 13.00 | 50-97.94 | 93.24 | 6.48 | 72.41-100 |

*Note:* ADHD = Attention-Deficit/Hyperactivity Disorder; CVLT = California Verbal Learning Task – Children's Version; Vocab = Vocabulary; LWID = Letter-Word Identification; WA = Word Attack; MCI = Metacognition Index; WMI = Working Memory Index; PSI = Processing Speed Index; PES = Phonemic Equivalency Score.

[a]z-scores with mean of 0. [b]Scaled scores with mean of 10. [c]Standard scores with mean of 100. [d]T-scores with mean of 50. [e]Percentile ranks.

*Group Differences on Measures of Executive Functioning*

A single-factor Multivariate Analysis of Variance was also conducted to assess if there were differences between the ADHD and RD groups on measures of executive function, including the BRIEF Metacognition Index (MCI), WISC Working Memory Index (WMI), and WISC Processing Speed Index (PSI). The assumptions of independence of observations and homogeneity of variance/covariance were checked and met. Bivariate scatterplots were checked for bivariate normality. MANOVA results revealed significant differences among the diagnostic categories with respect to the composite of dependent variables [Wilks' $\Lambda = .69$, $F\,(3, 78) = 11.73$, $p < .001$, partial $\eta^2 = .31$].

Follow-up univariate ANOVAs were conducted on each dependent variable in order to specifically determine which variables contributed to the significant global effect between the ADHD and RD groups on measures of executive function. Univariate between-subjects tests on each dependent variables indicated significant group differences for both the MCI and WMI scores [$F\,(1, 80) = 7.89$, $p < .05$, partial $\eta^2 = .09$ and $F\,(1, 80) = 24.71$, $p < .001$, partial $\eta^2 = .24$, respectively]. Specifically, children with RD had significantly lower scores on the WMI and children diagnosed with ADHD had significantly lower scores on MCI. The two groups did not differ significantly on the PSI [$F\,(1, 80) = 2.14$, $p = .148$, partial $\eta^2 = .03$].

*Summary of Supplementary Analyses*

Supplementary analyses exploring the unique contribution of each predictor variable in the explanation of the variability in the PES revealed that age and Letter-Word Identification were the only coefficients that significantly contributed to the prediction of the outcome variable. Additional exploratory analyses noted significant group differences on the PES and measures of executive functioning, particularly the Metacognition Index and Working Memory Index.

# Chapter V: Discussion

The purpose of the present study was to determine the utility of using spelling to aid in the explanation of reading performance. Specifically, this study explored the application of a spelling error analysis system as a method for differentiating between reading deficits resulting from executive dysfunction or poor language abilities. In order to best examine the relationship between executive function, language, and spelling achievement, this study was interested in investigating whether phonetic versus dysphonetic misspellings could be attributed to neurocognitive deficits in language and executive functioning in a sample of children at risk for reading failure. Of interest was whether there exists a dissociation of unique cognitive functions contributing to the explanation of deficits in spelling.

The role of phonological skills in the etiology of spelling achievement is well documented. Specifically, a linguistic skill deficit is noted as the most salient predictor of difficulties with sound-symbol correspondences and, in effect, phonetically accurate spelling. Therefore, it was hypothesized that children with language-based deficits would exhibit dysphonetic misspellings. There also exist robust findings indicating that neurocognitive factors associated with executive function, such as memory and metacognitive skills, contribute to spelling performance. Dysfunction in this area is thought to impact successful whole-word retrieval processes, resulting in an over-reliance on phonological skills to spell words. Therefore, it was also hypothesized that children with executive function deficits would demonstrate phonetically correct misspellings.

Hierarchical regression analyses allowed for investigation of the shared and unique contributions that various predictor variables made to a measure of phonemic equivalency of misspellings. Results from the study indicated that measures of language ability had a significant effect on phonological accuracy of misspellings when controlling for age and gender. Results also indicated that measures of executive functioning did not have a significant effect on the phonological accuracy of misspellings above and beyond that already accounted for by age, gender, and language-based skills. The findings clarify the cognitive and linguistic skills relevant to phonological accuracy of spelling, and, given the interrelationship of reading and spelling, provide insight into possible underlying deficits present in poor readers.

### *The Impact of Language on Phonemic Equivalency of Spelling*

Of particular interest to this study was the impact of linguistic skills on spelling. Consistent with previous research, strong relations between phonemic equivalency of spelling and performance on language-based tasks were found. Specifically, phonological accuracy of misspellings varied depending on children's performance on language and reading tasks. As children performed increasingly better on measures of language-based skills, their spelling errors became increasingly better approximations of their phonetic equivalents. These findings replicate patterns that have often been reported in the literature, citing the phonological core deficit as the most common etiology of reading and spelling difficulties (Garcia et al., 2010; Ouelette & Senechal, 2008; Savage & Federickson, 2006). Given the significant positive relationship between language tasks and phonemic equivalency of spelling, results suggest that analysis and use of phonemic information when encoding language (i.e. spelling) may provide insight into a child's language and reading achievement. Particularly, as corroborated in previously conceived models, severity of dysphonetic spelling errors may aid in identifying the degree of risk for language-based reading deficits and, thus, the benefit of establishing intervention approaches targeting language-based skills and their associated brain regions according to the dual-route model.

In addition to evaluating the combined effect of language components as a unified construct, this study offered insight into the relative predictive power of each language variable. Much like the existing body of research, the current study indicates support for the significance of Letter-Word Identification, or word reading, in the phonetic equivalency of spelling. Specifically, extensive evidence exists noting word reading and word spelling to be similar processes across developmental stages, with word reading knowledge having a direct affect on phonological representations of spelling words (Ball & Blachman, 1991; Bear, Templeton, & Warner, 1991; Berninger, Abbott, Abbott, et al 2002; Griffith, 1991; Ritchey, Coker, & McCraw, 2010). The current data provide further support for this well known relationship. It was surprising to find, however, that results suggested only word reading made sizable and statistically significant unique contributions to phonemic accuracy of spelling. Vocabulary, verbal memory, and phonemic decoding measures did not significantly contribute to the prediction of the phonetic equivalency of spelling.

Considerable evidence exists confirming the relation between vocabulary and verbal memory with word reading; however, the role of these components in phonetic spelling has not received much attention. While findings were non-significant, further empirical investigation of the role of verbal memory and vocabulary knowledge in phonetic accuracy of spelling is needed.

Of great interest is the finding that phonological decoding, as measured by the Word Attack subtest, did not add a significant amount of variance on the phonemic equivalency score. While less is known about the relationship of phonological decoding with spelling than with reading, many have proposed that phonemic awareness skills such as these are necessary to both create sub-lexical segments and match letters with individual phonemes in order to accurately represent sounds in print (Ehri et al, 2001, Tangel & Blachman, 1992, 1995). Similar to findings from the current study, Mann (1993) reported only slight correlations between phonemic awareness and phonological spelling among a sample of kindergartners with poor word reading skills, suggesting that these skills are not measuring the same construct. However, findings from Mann and the current study are contrary to much of the literature, which purport a bidirectional relationship between phonemic awareness and phonological spelling, with one being a proxy for the other (Manis, Custodio, & Szeszulski, 1993; Snowling, 1995; Torgesen & Davis, 1996; Treiman, 1993; Wagner & Torgesen, 1987). For instance, Muter (1998) and Caravolas, Hulme, & Snowling (2001) found strong associations between phonological awareness skills, particularly sound segmenting, and phonological spelling. Both studies concluded that phonemic awareness skills are needed to translate phonemes into graphemes and thus can be used to identify causal or maintaining factors for spelling impairment. Further, a meta-analysis conducted by Ehri et al. (2001) revealed that phonemic awareness training resulted in increased performance on spelling post-test measures, leading them to conclude that phonemic awareness is a significant component in spelling acquisition as well. Therefore, it was expected that letter-sound knowledge, as captured by the Word Attack subtest, would facilitate phonologically accurate spelling.

There exist several possible issues contributing to the non-significant findings. First, considering the relatively robust bivariate correlation between Letter-Word Identification and Word Attack subtests, it is likely that the variance was subsumed by other measures in the regression analyses and that Word Attack was a redundant variable. This was further demonstrated by the stronger bivariate correlation between Letter-Word Identification and PES when compared to the bivariate correlation of Word Attack and PES. Second, phonological awareness is a complex metalinguistic ability. As such, an individual phonemic awareness task may not be able to adequately assess an individual's competence in this area. The amount of variance accounted for by the Word Attack subtest may not have been representative of the broader construct of phonological awareness abilities, such as that provided by the Comprehensive Test of Phonological Processing (CTOPP; Ritchey et el., 2010; Wagner et al., 1999); therefore, the results may not have indicated the true amount of variance accounted for by this construct in the outcome measure. It has also been suggested that phonemic manipulation tasks capture phonological awareness better than blending tasks, such as Word Attack, particularly across age and developmental levels (Lombardino, Riccio, Hynd, & Pinheiro, 1997).

However, to control for such developmental influences, chronological age was entered into the regression equation first. Examination of such measures as the CTOPP and Spelling of Sounds from the WJ III-ACH may provide further insight into role of phonological awareness that was unable to be captured by Word Attack alone (Ritchey et al., 2010). Lastly, despite adequate power, small sample size could contribute to an inability to find an effect should one exist. Current findings provide evidence that the Word Attack subtest was not a significant predictor of phonemic equivalency of spelling in this sample. Previous research and results from the current study suggest that there is much to discover in this area and that it may be beneficial to further investigate the relationship between word reading, aspects of phonological awareness, and phonological spelling.

### *The Impact of Age on Phonemic Equivalency of Spelling*

As previously mentioned, there exist developmental influences impacting a child's performance on spelling. Variance associated with such developmental phenomena was removed by entering chronological age into the model first in order to then evaluate the relative predictive impact of the remaining variables. This is particularly important because spelling test items were administered relative to age and grade level, with items ordered from least to most difficult and older children largely spelling longer and more complex words. Age was shown to have a significant effect on phonemic accuracy of spelling. As children increased with age, they demonstrated greater proficiency in capturing a word's phonology in print. Results are consistent with existing behavioral models and reflect a chronological developmental progression of spelling sophistication, with children gaining greater integration and application of letter-sound correspondences in their spelling attempts (Bourassa et al., 2011; Ganske, 1999; Lutz, 1986; Masterson & Apel, 2010; Read, 1975; Ritchey et al., 2010; Willows & Scott, 1994). According to theories on the developmental stage process of spelling, as children attain alphabetic knowledge they learn phoneme-to-grapheme correspondences and use phonetic cues to decode words. Age likely accounts for significant variance in phonemic equivalency due to the effect of this typical developmental trajectory of spelling. Younger children have less well-developed phonological skills, resulting in more inconsistent use of phonological systems and thus a lower phonemic equivalency score. Conversely, older children may be more adept at representing sounds within spoken language given instructional exposure and development. The current results clarify age as a factor in phonological spelling and demonstrate the importance of using chronological age as a control variable in order to extract the influence of overall developmental progression and to determine the components accounting for differences in spelling capacity above and beyond that demonstrated by typical developmental changes.

### *The Role of Executive Function in Phonemic Equivalency of Spelling*

This study is one of the first to look at the association between executive functioning and patterns of misspellings, integrating theoretical models in the fields of literacy and neuropsychology. The aim was to identify if additional deficits beyond problems with metalinguistic tasks were present and could be attributed to executive functioning performance. The phonological accuracy of misspellings was not found to be significantly related to children's performance on executive functioning tasks, suggesting that language and age were the only identified factors contributing to a child's pattern of misspellings in this sample. The present study thus provides little support for the lexical pathway system of the dual-route model when applied to a sample of participants at high risk for reading failure. The non-significant results add to a steadily accumulating body of recent research evaluating executive functioning processes and the effect on spelling and reading performance. Therefore, the finding that executive function does not add a significant amount of the variance explained on the phonemic equivalency score extends previous research efforts attempting to clarify the role of executive functioning in language-based difficulties (Bental & Tirosh, 2007; Mayes et al., 2000; Rucklidge & Tannock, 2002).

While results lack information regarding underlying impairment beyond language and demographic information, only approximately 53% of the variance in phonological spelling could be predicted by knowing individuals' age, gender, and language ability. This is a sizable amount of variance explained, but the remaining variability unaccounted for provides justification for further review. Because Reading Deficit and ADHD populations account for a substantial number of students demonstrating poor academic performance in reading domains and capture various neurocognitive profiles contributing to these difficulties, further analysis of group differences was deemed useful (Marzocchi et al, 2008; Re et al., 2007). Specifically, exploratory analyses revealed that ADHD and Reading Deficit groups differed significantly in phonological spelling performance.

While results from the regression analysis suggest that variability in the phonological equivalency score could not be explained by executive functioning performance above and beyond demographic factors or language abilities, findings from exploratory analyses indicate that children with Reading Deficits demonstrated significantly less phonologically accurate spelling attempts than children diagnosed with ADHD. Group differences on the phonemic equivalency score suggest that something is different across misspellings for these two groups. Differences in performance of the ADHD group on the phonemic equivalency score in contrast to the Reading Deficit group provides evidence for two distinct underlying cognitive processes affecting spelling and the validity of further investigating the potential to infer differential diagnostic categories using a phonological spelling analysis. Thus, questions arise as to whether the uniqueness can be attributed to factors beyond language.

Research has revealed robust classification models distinguishing various neurocognitive factors related to reading and spelling difficulties. Factors have included primarily language, but also aspects of executive functioning (Morris et al., 1998). ADHD is commonly associated with deficits in executive function and general cognitive control (Alderson et al., 2007); however, neuropsychological assessment studies also reveal disturbances in executive function in children with reading deficits. While several studies question whether these are overlapping deficit areas disrupting reading acquisition, evidence points to the ability to discriminate between ADHD and Reading Disorders according to executive function profiles (Bental & Tirosh, 2007; Marzocchi et al, 2008; Pennington et al, 1993). To further understand performance on executive functioning measures within the current sample, this study offered additional examination of patterns of group differences.

Exploratory analyses revealed significant group differences in executive functioning, particularly on measures of working memory and metacognition. Consistent with much of the literature, children diagnosed with ADHD were rated significantly lower on the Metacognition Index than children identified with Reading Deficits (Alderson et al., 2007; Anderson et al., 2008; Marzocchi et al., 2008). Interestingly, children diagnosed with ADHD performed significantly better on working memory tasks than children identified with Reading Deficits, which is contrary to Barkley's model of executive functioning noting poor working memory as an ADHD phenomenon (Barkley, 1997). While working memory is shown in the literature to be an area of marked deficit among children with reading deficits (McCallum et al., 2006; Ouellette & Senechal, 2008), it is generally identified as a measure of executive function and was thus suspected to be more impaired in children with ADHD (Barkley, 1997; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Although limited data exists comparing working memory between these two particular groups, a recent comparison study by Bental & Tirosh (2007) reported poorer performance for working memory in an ADHD plus reading deficit combined group when compared with ADHD only and control groups. Additionally, evidence does exist looking more broadly at working memory in children demonstrating reading difficulties. Specifically, findings from the current study are consistent with studies investigating anatomical explanations for reading failure among heterogeneous groups in which atypical activation in the left prefrontal regions and middle frontal gyrus, which are associated with working memory, were noted (Gabrieli, 2009; Hoeft et al., 2007; Shaywitz et al., 1998). Similarly, Turkeltaub et al. (2003) noted the importance of working memory in the acquisition of reading. These findings, along with findings from the current study, support Baddeley's multi-component model of working memory, particularly the phonological loop of working memory, which note that working memory is critical in language development and processing of phonologically encoded information (Baddeley, 1986, 1996; Gathercole & Baddeley, 1989).

Results from the current study corroborate previously conceived models asserting ADHD and Reading Deficit groups present unique deficits, suggesting the ability to differentiate ADHD from Reading Deficits based on their clinically different profiles. While group differences are present, results from the regression analysis suggest that tests of executive function, a domain in which deficits are inherent in both reading deficit and ADHD symptom clusters, may not explain the variance in these at-risk readers' degree of phonological spelling. One possible explanation for this non-significant finding may relate to theoretic issues with the concept of Executive Functioning. Measures used in the current study represent widely accepted tests of executive functioning commonly used for assessment of planning, problem solving, attention and memory functions, which have been found to be impaired in children with reading difficulties. However, controversy from both neuropsychological and cognitive studies of executive function exists regarding the extent to which these different measures can be attributed to a unitary construct. Some believe that executive function components are generally associated with similar underlying mechanisms or abilities, while others assert that they are non-unitary and therefore represent multiple factors rather than a single construct (Miyake et al., 2000; Welsh, Pennington, & Groisser, 1991). Current debates in the literature and findings from the present study indicate that it may be beneficial to narrow the construct of executive functioning by investigating the unique contribution of different components, particularly the visual versus phonological loop suggested by Baddeley, in the explanation of phonological spelling.

Another possible factor contributing to the non-significant relationship between executive functioning and the phonemic equivalency score may be related to the previously described impact of working memory on language development and phonological processing. Several studies have suggested that working memory deficits could be subsumed under the broader paradigm of phonological processing (Bowey, Cain, & Ryan, 1992; Wagner et al., 1994), while others support the independence of working memory and phonological processes (Gathercole, Willis, & Baddeley, 1991; Wagner, 1988). Specifically, working memory has been implicated in phonemic awareness tasks, word reading, and vocabulary, all of which comprised the language block in the current regression model (Kroese et al., 2000; McCallum et al., 2006; Ouellette & Senechal, 2008). These findings are further supported by the intercorrelations matrix, which noted working memory significantly correlated with vocabulary, word reading, and phonological decoding in the current sample. Considering the relatively robust correlation between working memory and language measures, questions arise as to whether working memory is either a redundant variable or, rather, more accurately contributes to the language predictor variable block. Against this view, recent studies have found small independent effects of memory in spelling (Pennington, Cardoso-Martins, Green, & Lefly, 2001; Savage et al., 2005). It is not yet known whether working memory contributes to phonological spelling beyond its association with phonological processes and language-based tasks, supporting the need for further exploration in this area.

## *Limitations and Future Directions*

While the sample in the current study represents characteristics associated with at-risk readers, aspects unique to the population may limit generalizability of findings to larger populations. Specifically, participants were from a private neuropsychological clinic in which most families utilize self-pay methods in order to obtain services. As such, participants were suspected to be of predominantly middle to high socio-economic status. Recruitment from a clinic setting may have also affected the severity of symptom presentation, with the current population likely demonstrating higher functioning as compared to community or school samples. As previously reported in the descriptive statistics of the data, the sample also consisted of primarily Caucasian children. This has significant implications regarding limited generalizability of the findings to more ethnically diverse populations. Therefore, similar studies with more diverse populations and sampling procedures are needed to extend the results of this study. Lastly, while power analyses revealed adequate power in the present study, a larger sample size may afford greater sensitivity in detecting significant findings.

Another limitation to this study is that the design did not fully distinguish between distinct diagnostic groups. This study only investigated cognitive profiles from a sample of children diagnosed with ADHD and a reading deficit sample containing some comorbid ADHD diagnoses. A group with only reading deficit symptoms was absent in this study; therefore, it was not possible to test competing hypotheses on the specific neuropsychological profile of ADHD, Reading Deficit, and their comorbidity. Furthermore, the study design did not distinguish between typical or low risk readers, which would more accurately represent the heterogeneity of students in classroom. Although performance was normally distributed within the sample on measures of executive functioning, it is possible that the exclusion of a pure reading deficit group contributed to limited findings within this domain due to restricted variability on the measure. In future studies it would be useful to include distinct diagnostic groups and a control group in order to gain a more expansive representation of the relationship between performance on a phonological spelling measure and a variety of cognitive domains, as well as factors contributing to differences among clinical groups.

As previously discussed, the spelling analysis system was sensitive to the effects of age and development. In accordance with standardized administration, words presented varied based on the individual's grade level. Estimates of an individual's phonetic accuracy of misspellings may have depended on the type, number, and length of words presented, including number of syllables and phonemes (Fischer, Shankweiler, & Liberman, 1985). Therefore, it is possible that word complexity contributed to unexplained variance within the phonemic equivalency score. While a set word list may not be a feasible option within a clinical setting, diagnostically it may be informative.

The current study presents a cross sectional analysis of the effects of language and executive function at a single point in development. Given the effects of age and the developmental stage process of spelling, future research is also needed to evaluate this relationship longitudinally and, therefore, at different times in development in order to assess intra-individual change as spelling becomes more sophisticated.

### *Conclusions and Implications*

Despite emerging data on the neurobiological correlates of reading difficulties and extensive research attempting to delineate neuropsychological processes of at-risk readers, controversy remains about how to best identify and treat reading deficits. Furthermore, efforts to recognize and prevent reading deficits through response to intervention practices are costly and have been largely ineffective, with inadequate response rates as high as 78 percent (Foorman, Francis, Winikates, et al., 1997; Klingner, Vaughn, Hughes, Schumm, & Elbaum, 1998; Orlando & Rivera, 2004; Torgesen, et al., 2001). The current study sought to contribute to existing neuropsychological profiles of struggling readers and to provide further insight into the definition and classification of reading difficulties in order to ultimately improve treatment selection and, in effect, response to intervention outcomes.

Results indicated a link between language-based skills, particularly word reading, and the phonological accuracy of spelling, with lower performance on language tasks predicting poorer phonetic approximations. These results are both theoretically and clinically relevant in that they confirm the importance of linguistic knowledge in phonological spelling. Tasks of executive functioning were not found to significantly contribute to performance on phonological spelling; however, analysis of group differences suggest that ADHD and Reading Deficit samples demonstrate unique cognitive profiles, including distinct performances on phonological spelling, despite their similar presentation of reading difficulties within the population. This finding has implications for the need to further examine characteristic deficits (i.e. language and executive functioning) associated with each of these diagnostic groups in the performance on reading and spelling measures. With that said, the current study indicates the importance of further clarifying the constructs of language and executive function prior to examining their effect on spelling.

The current study highlights the developmental implications and importance of considering age when assessing spelling. Research that fails to account for the effect of the typical developmental trajectory of spelling acquisition will invariably overestimate findings and lead to misinterpretation of data. As previously mentioned, further examination of ways to isolate factors influencing spelling within the context of age and development would be beneficial.

This study also has implications for looking beyond phonetic and dysphonetic misspellings in order to capture important nuances in print, beyond that of phonology and more in line with developmental stage theories. While many studies, including the present study, have investigated one or two characteristics of spelling errors, no empirically based studies simultaneously account for multiple components of spelling. The use of spelling systems that address other factors involved in obtaining accurate spelling skills, such as orthography (e.g., knowledge of letter sequence, variety of phoneme representations), morphological relations among words, and mental orthographic images, may provide further insight into the neurocognitive factors contributing to spelling acquisition and, in effect, reading (Arndt & Foorman, 2010; Bourassa et al., 2011; Varnhagen, Boechler, & Steffler, 1999). Such studies would move beyond language and sound-based spelling, incorporating higher-level influences that may be more directly related to effects of executive functioning. Although fraught with measurement issues, such spelling systems may give greater attention to the complexity and interaction of various strategies and sources of information involved in spelling.

The present findings have implications for the utility of studying reading through the integration of multiple cognitive processes as represented by spelling. The use of an analysis of spelling errors as a diagnostic data source holds promise for better understanding of the neurocogntive underpinnings and, in effect, alignment of instructional methods based on the child's need (Arndt & Foorman, 2010). Although speculative, direct intervention studies looking at treatment placement and outcomes based on phonetic versus dysphonetic spelling, with interventions developed to target underlying deficit areas, would help evaluate the potential importance of utilizing spelling as a mechanism for determining appropriate interventions and thus increased responsiveness.

## Appendix A

Austin Neuropsychology, PLLC

Patient Name:______________________________ Patient #_______________

**Research Participation:** In our effort to learn more about how people function and how to help our patients, we sometimes carry out research studies using past test data. In this research, ***all identifying information is removed and confidentiality is protected.*** Also, occasionally we contact past patients to see if they are interested in participating in new research studies. Your decision to participate or decline to participate in research will in no way affect your relationship with Austin Neuropsychology or our commitment to your clinical care. If you agree to research participation, please indicate your consent by initialing below:

I _____ give (or) _____ do NOT give permission for you to contact me about research participation.

I _____ give (or) _____do NOT give permission for you to use the patient's testing data for research / teaching purposes.

____________________________________ __________________
(Signature of Patient or Parent/Legal Guardian) Date

____________________________________
Name of Parent /Legal Guardian (if applicable)

Email address:____________________________________________________

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**For Office Use Only**

**Clinic Number** ____________________

**UT**_______

## Appendix B

**FAMILY DATA**
(To be filled out by parents)

Date: ____________________

Child's Name: ________________________________ Adopted? ______ Birthdate: ___________ Age _____

Home Address: ________________________________________ Home Phone: ____________________

School: ________________________________ Grade: _________ School Phone: ________________

Father's Name: ________________________ Age: _________ Education: ____________________

Employment: ____________________________________________________________

Mother's Name: ________________________ Age: _________ Education: ____________________

Employment: ____________________________________________________________

Other Children in the Home:

Name & Age: ________________________ Name & Age: ________________________

Name & Age: ________________________ Name & Age: ________________________

Other relatives or persons living in the home:

____________________________________________________________

____________________________________________________________

UNDERLINE THE APPROPRIATE ITEMS BELOW:

(Our, My) reason for bringing child in today is (routine physical check-up, physical problems, speech problems, poor school work, behavior problems, not doing well at home or school).

Problem has been going on for (weeks, months, year or more).

**FAMILY** (underline correct answers)

Child lives with (both his own parents, step-father, step-mother)

(Father, mother, neither, both) had similar troubles.

Child (disrupts, gets along with) family.

Child has mostly been a source of (pride, worry, friction) for family.

Parents (agree, disagree) on how to discipline child.

Discipline has been (strict, lenient, inconsistent, all of these).

Marital troubles are (mild, moderate, severe, none).

Parents have problems of (alcoholism, chronic disease, mental illness, none).

Other children in the home have problems with (school behavior, grades, illness, emotional adjustment, none).

## PREGNANCY HISTORY - Mother

While you were pregnant with this child, were you under a doctor's care? YES___ NO___

| During this pregnancy did you have: | Yes | No | When | Describe |
|---|---|---|---|---|
| Anemia | | | | |
| Elevated blood pressure | | | | |
| Toxemia | | | | |
| Swollen ankles | | | | |
| Kidney disease | | | | |
| Heart disease | | | | |
| Bleeding | | | | |
| Measles | | | | |
| German measles | | | | |
| Flu | | | | |
| Other virus | | | | |
| Other illness | | | | |
| Vomiting | | | | |
| Injury | | | | |
| Medication during pregnancy | | | | |
| Threatened miscarriage or early contractions | | | | |
| Alcohol consumption | | | Amount: | |
| Drug abuse | | | Type/Amount: | |
| Smoking | | | Amount: | |

## BIRTH HISTORY

How many hours from first contractions to birth?___

Were you given medications? YES___ NO___ What kind? ___

Did you have natural childbirth? YES___ NO___

Were you under anesthesia during childbirth? YES___ NO___ Don't know___

Was labor induced? YES___ NO___ Was induced labor planned? YES___ NO___

Was this a breech (feet first) delivery? YES___ NO___

Was the delivery unusual in any way? YES___(How?___ NO ___

Did you have a cesarean? YES___ NO___Complications?___

Name any medical problems.___

Duration of pregnancy. ___ What did the baby weigh?___

Did you have twins? YES___ NO___ Which born first?___

Did this baby have: breathing problems? YES___ NO___ Don't know___
cord around neck? YES___ NO___ Don't know___

Did this baby cry quickly? YES___ NO___ Don't know___

Was the baby's color normal? YES___ NO___ Blue?___Yellow?___Don't know___

Was oxygen used for the baby? YES___ NO___ If so, how much?___

Did you take the baby home with you from the hospital? YES___ NO___ Describe:___

Did you have problems with feeding? YES___ NO___ Describe:___

Was the baby normally active? YES___ NO___Describe:___

**DEVELOPMENTAL HISTORY*** (As best you remember)

Age held head up__________, age turned over__________, age smiled at parents__________,
age crawled__________, age sit__________, age pull up at crib__________,
age walk with help__________, age walk alone__________, bottle fed?__________,
breast?__________, age weaned__________, age say 4-10 words__________,
age use sentences__________, speech problems?__________, did he/she hold out arms and want to picked up?__________, age say "No, no" to everything__________,
shy or timid__________, liked attention?__________, friendly baby?__________,
affectionate?__________, wanted to be left alone__________, more interested in things than in people?__________, stubborn?__________, ate well?__________,
feed self, age__________, temper tantrums?__________, breath holding?__________,
tears up toys more than normal?__________, much too active?__________,
bowel trained, age__________, dry at what age?__________, age helped with dressing__________,
age dressed alone__________, right or left handed__________, age this settled?__________,
well coordinated?__________, clumsy?__________, good with hands?__________,
blank spells?__________, falling spells?__________, dare-devil behavior?__________,
impulsiveness?__________, unusual fears?__________, sleep problems?__________,
rocking?__________, head bumping?__________.

**SCHOOL HISTORY** (underline correct answers)

According to school the child's I.Q. is (average, below average, above average, I don't know).

Since first grade, school personnel have reported (no serious problems, problems with behavior, speech, reading, writing, spelling, math).

Child has (been in Special Education Class, failed a grade, been tutored, made satisfactory grades).

School personnel have reported through the years that the child (adjusts to other children, doesn't adjust).

Child (likes school, hates school, is indifferent).

* - If additional space is needed to answer any questions, use above space.

## Appendix C

Prior to the onset of this study and as part of the pre-existing assessments, a licensed neuropsychologist conducted a clinical interview with each participant and his/her parent(s) or guardian(s). During the interview, the neuropsychologist of record collected developmental, medical, and family background information pertaining to the presenting complaint, as well as a more detailed account of the child's current referral concern. Based on this information and information from a structured developmental and family history form (Appendix B), the neuropsychologist chose an appropriate assessment battery specific to the family and child's needs.

Although each neuropsychological assessment was individualized to best suit the referral concerns, the test battery generally included assessments in the following domains: motor functioning, auditory functioning, memory, attention, cognitive functioning, academic achievement, and social-emotional functioning. The testing was conducted at Austin Neuropsychology Clinic in a single or multiple sessions approximately 6 to 8 hours in duration, with breaks provided as needed. Parents were given parent and teacher checklists/rating scales during the clinical interview or via mail and asked to return them at the time of the testing appointment.

During the assessment, the neuropsychologist conducted a clinical motor exam with the child. Professional psychometrists or graduate students from educational, counseling, and clinical psychology programs trained in individual assessment conducted the remainder of the assessment battery, including, but not limited to, tests of cognitive, achievement, and executive functioning. All graduate students had completed doctoral level courses in psycho-educational, social-emotional, and neuropsychological assessment. Additionally, all graduate students and psychometrists also completed training in administration and scoring for each measure included in the neuropsychological assessment battery. In order to ensure reliability and accuracy of administration and scoring of the neuropsychological assessments, graduate students were observed by senior level students or psychometrists. Additionally, a subset of completed assessment files was randomly chosen for review and rescoring. Graduate students received approximately one hour of supervision from the licensed neuropsychologist of record for each case.

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